

A. Pastore · A. V. Yuceturk · P. Trevisi

Evaluation of voice and speech following subtotal reconstructive laryngectomy

Received: 10 April 1996 / Accepted: 19 September 1997

Abstract Subtotal reconstructive laryngectomy (SRL) can be used to preserve voice in the treatment of selected laryngeal carcinomas. This study was designed to analyze both voice and speech results achieved after SRL in 14 male patients, aged from 48 to 73 years. Surgery was performed between 1983 and 1993. Fundamental frequencies, ranges of frequency, intensities, and intensity ranges were established using an S.I. 80 Philips AAC 600 Audio Active Comparative Language System. Five prolonged vowels and six phonetically balanced sentences were recorded on a tape positioned at a distance of 30 cm from the mouth of each patient during a 3-min recording time. The recorded material was then evaluated by a panel of ten trained listeners who were asked to consider the qualitative parameters and perceptual characteristics of voice and speech according to a scorecard modified from one devised by Voiers and Formigoni. Although a decrease was determined in Fundamental Frequency and intensity of the voice when compared to normal values, the quality and perception of speech were found to be satisfactory. The verbal message could be understood almost exactly by means of constant sonority, correct articulation and improved pneumophonic coordination. These values demonstrate that the new voice achieved after SRL is less sonorous and allows for understandable and socially acceptable speech.

Key words Subtotal reconstructive laryngectomy · Voice · Speech · Communication

A. Pastore (✉) · P. Trevisi
ENT Clinic of Ferrara University Medical Faculty,
Hospital of St. Anna, I-44100 Ferrara, Italy

A. V. Yuceturk
ENT Clinic of Celal Bayar University Medical Faculty,
Manisa, Turkey

Introduction

Subtotal reconstructive laryngectomy (SRL) is a supracricoid laryngectomy that has been used for the treatment of selected laryngeal carcinomas in order to preserve voice. The procedure, however, cannot be used for advanced (T4) laryngopharyngeal tumors, cancers invading the cricoid cartilage or cricothyroid membrane, and/or exceeding 5 mm in their subglottic extensions. The type 1 SRL involves the preservation of one or both arytenoids and can be applied in those cases of supraglottic neoplasms extending to the glottis, as well as in glottic cancers when cordectomy is not feasible. The type 2 SRL involves removal of both arytenoids and is applicable to those cases of intrinsic supraglottic or glottic tumors which extend to both arytenoids.

When employing the arytenoid-preserving technique to restore laryngeal function, the recurrent and superior laryngeal nerves must be preserved. The base of the tongue is pulled back and downward close to the cricoarytenoid structure while achieving the cricohyoidopexy. In the second type of SRL two pseudoarytenoids are constructed together with pulling the base of tongue back and downward.

Successful deglutition without aspiration and a physiologic respiratory tract can be maintained by logopedic rehabilitation. The surgical technique and oncologic and functional results of SRL have been reported previously [3, 4]. However, there has been no significant objective report on phonatory results published in the English if Laccourreye's [5] preliminary report is excluded. This study was designed to analyze voice and speech results achieved after SRL.

Materials and methods

The study population included 14 male patients whose ages ranged from 48 to 73 years (average, 62.4 years). All underwent SRL between 1983 and 1993 for the treatment of squamous cell carcinomas of the endolarynx. Surgery was the only therapeutic procedure for all patients and no pre- or post-operative irradiation was given. Patients participating in this study were those who had finished

Table 1 Scorecard used for evaluating each patient's voice and speech

Tonal pitch	Very low	-5	_ _ _ _	0	_ _ _ _	5	Very high
	Non-variable	-5	_ _ _ _	0	_ _ _ _	5	Uncontrolled variations
Intensity	Very low	-5	_ _ _ _	0	_ _ _ _	5	Very high
	Non-variable	-5	_ _ _ _	0	_ _ _ _	5	Uncontrolled variations
Quality	Normal	0	_ _ _ _	5	Most breathy		
	Normal	0	_ _ _ _	5	Most harsh		
	Normal	0	_ _ _ _	5	Most hoarse		
	Normal	0	_ _ _ _	5	Most tense		
Diphony	Absent	0	_ _ _ _	5	Always present		
Whispering	Absent	0	_ _ _ _	5	Always present		
Glottal attack	Soft	-5	_ _ _ _	0	_ _ _ _	5	Hard
Nasality	Hyponasality	-5	_ _ _ _	0	_ _ _ _	5	Hypernasality
Duration	Speech duration		Normal	0	_ _ _ _	5	Very long
	Rhythm		Normal	0	_ _ _ _	5	Non-fluent
General considerations	Intelligibility	Non-intelligible	0	_ _ _ _	5	Normal	
	Pleasantness	Unpleasant	0	_ _ _ _	5	Normal	
	Acceptability	Not acceptable	0	_ _ _ _	5	Normal	

phoniatric rehabilitation at least 6 months before the present evaluation and were followed at least 1 year postoperatively. Additionally, nasogastric feeding tubes and tracheotomy cannulas were successfully removed by the end of the first postoperative month. Voice rehabilitation started after the second month, and was given twice a week for the first 3 months and once a week during the following 2 months.

Fundamental frequency (F_0), range of frequency (ΔF), intensity (I_0), and intensity range (ΔI) were established using an S.I. 80 Philips AAC 600 Audio Active Comparative Language System. F_0 values were determined by registration and analysis of prolonged vowels in all patients. These voice emissions consisted of a periodic verbal signal and part noise. I_0 values of the voices were recorded in a basal condition of phonation, without vocal-attack mechanisms. I_0 data were given in dB SPL and then referred to as dB nHL above the environmental noise in order to compare the sounds produced to a daily listening condition. Registration was conducted in a quiet room having an average noise level of 30 dB.

Five prolonged vowels (/a/, /e/, /i/, /o/, /u/) and six phonetically balanced sentences were recorded with a tape recorder positioned at a 30-cm distance from each patient's mouth. A 3-min recording time was used for each patient. The recorded material was then evaluated by a panel of ten trained listeners who were third-year students from the University of Ferrara School for Speech Therapy. All testing was done in a silent room and at a 1-m distance from the tape recorder.

Listeners were asked to consider the speech according to a scorecard modified from Voiers and Formigoni [8, 18]. This card is illustrated in Table 1 and provided a scale for evaluating the main voice quality features, but also included a final judgement on such parameters as intelligibility, acceptability and pleasantness. 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.

Tenseness, harshness, hoarseness and breathiness were scored as 0 in the good performers and as 5 in the worst voices. Intelligibility, acceptability and pleasantness were scored as 5 in the best subjects and 0 in the worst ones (Table 1). Scores of the parameters were summed and averaged for each patient. Results were then analyzed using linear regression with Pearson's correlation.

Results

Results are summarized in Table 2. Values for each parameter are shown horizontally, beginning from the best to the worst in cumulative percentiles in Table 3. Correlations among the parameters are shown in Table 4. Positive significant correlations were determined between acceptability and intelligibility, acceptability and pleasantness, and intelligibility and pleasantness. Negative significant correlations were found between pleasantness and hoarseness, pleasantness and harshness, intelligibility and harshness, and acceptability and harshness.

Discussion

Several parameters have been used to measure vocal function. These include fundamental frequency, intensity, jitter, shimmer, noise-to-harmonic ratios, maximum phonation time, speech rate (words or numbers per minute or per expiration) [2, 5, 6, 11, 15, 16]. However, few authors have shown a consensus on even a minimum battery of measures. As a result, there is a lack of standardization with tasks, protocols and measures, as well as absence of comprehensive normative data [13]. Most authors now agree that perceptual scores (acceptability, intelligibility and pleasantness) and qualitative factors (breathiness, hoarseness, harshness and tenseness) are the most important values for evaluating voice and speech [1, 8, 9, 11, 13, 14, 18]. For this reason, we used these parameters for evaluating our patients following SRL.

The voice in patients following SRL seems to be produced by the vibration of the arytenoid(s) and the mucosal layers of the tongue base and the neoglottis. Movements of arytenoids can be observed during endoscopy and are due to the extrinsic muscles of the larynx. Recurrent and

Table 2 Summarized voice and speech results in patients following SRL

Patient number	F ₀ (Hz)	ΔF (Hz)	I ₀ (dB)	ΔI (dB)	Intelligibility	Pleasantness	Acceptability	Breathiness	Hoarseness	Harshness	Tenseness
1	105	0	20	5	3.2	0.8	2.8	0.3	2.4	2.7	0.0
2	80	30	25	20	3.2	2.0	3.5	0.5	2.0	1.6	0.5
3	110	60	30	20	3.6	0.9	3.0	1.3	3.3	1.7	0.0
4	100	40	30	20	3.9	2.0	3.6	0.7	2.1	1.2	0.0
5	120	30	20	10	4.1	2.1	3.6	2.1	2.1	1.2	0.3
6	130	50	10	15	4.1	2.8	3.6	0.8	2.1	1.0	0.5
7	100	20	20	20	4.2	2.7	4.1	0.1	1.7	0.5	0.0
8	120	30	30	20	4.3	2.1	3.9	0.5	3.0	0.4	0.4
9	110	20	20	15	4.3	2.1	4.1	0.0	3.1	0.3	0.5
10	100	160	30	25	4.3	2.9	4.1	1.6	3.0	0.0	0.0
11	120	100	20	20	4.4	3.4	4.4	0.4	2.7	0.0	0.0
12	120	30	20	10	4.4	3.5	4.2	2.2	1.2	0.1	0.6
13	100	40	25	20	4.8	3.5	4.6	0.7	1.7	0.2	0.4
14	110	80	30	23	5.0	4.8	5.0	0.1	0.3	0.0	0.0
Mean	108.9	49.3	23.6	17.4	4.13	2.54	3.89	0.81	2.19	0.78	0.23
SD	12.7	40.8	6.0	5.6	0.52	1.07	0.59	0.72	0.82	0.82	0.25
Max-min	80–130	0–160	10–30	5–25	3.2–5.0	0.8–4.8	2.8–5.0	0.0–2.2	0.3–3.3	0.0–2.7	0.0–0.6

Table 3 Cumulative values for voice and speech qualities in patients after SRL

	Cumulative percent (%)													
	7.1	14.3	21.4	28.6	35.7	42.9	50.0	57.1	64.3	71.4	78.6	85.7	92.9	100
F ₀ (Hz)	130	120	120	120	120	110	110	110	105	100	100	100	100	80
ΔF (Hz)	160	100	80	60	50	40	40	30	30	30	30	20	20	0
I ₀ (dB)	30	30	30	30	30	25	25	20	20	20	20	20	20	10
ΔI (dB)	25	23	20	20	20	20	20	20	20	15	15	10	10	5
Acceptability	5.0	4.6	4.4	4.2	4.1	4.1	4.1	3.9	3.6	3.6	3.6	3.5	3.0	2.8
Pleasantness	4.8	3.5	3.5	3.4	2.9	2.8	2.7	2.1	2.1	2.1	2.0	2.0	0.9	0.8
Intelligibility	5.0	4.8	4.4	4.4	4.3	4.3	4.3	4.2	4.1	4.1	3.9	3.6	3.2	3.2
Tenseness	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.4	0.5	0.5	0.5	0.6
Harshness	0.0	0.0	0.0	0.1	0.2	0.3	0.4	0.5	1.0	1.2	1.2	1.6	1.7	2.7
Hoarseness	0.3	1.2	1.7	1.7	2.0	2.1	2.1	2.1	2.4	2.7	3.0	3.0	3.1	3.3
Breathiness	0.0	0.1	0.1	0.3	0.4	0.5	0.5	0.7	0.7	0.8	1.3	1.6	2.1	2.2

Table 4 Correlations among the various parameters studied for voice and speech after SRL

Correlations (r)	Breathiness	Hoarseness	Harshness	Tenseness	Intelligibility	Pleasantness	Acceptability	I ₀
F ₀	0.273	0.058	-0.235	0.182	0.371	0.171	0.085	-0.448
I ₀	-0.006	0.076	-0.108	-0.411	0.088	-0.008	0.126	
Acceptability	-0.161	-0.518	-0.909**	0.075	0.916**	0.934**		
Pleasantness	-0.032	-0.686**	-0.815**	0.083	0.853**			
Intelligibility	-0.009	-0.412	-0.889**	0.059				
Tenseness	0.215	-0.071	-0.146					
Harshness	-0.027	0.226						
Hoarseness	0.026							

* $P < 0.01$; ** $P < 0.001$

superior laryngeal nerves which innervate the lateral and posterior cricoarytenoid muscles have to be preserved during surgery and have a role in residual laryngeal vibrations [17].

We observed that F₀ and I₀ did not primarily affect the quality and perception of voice and speech (Table 4).

Qualitative factors were also found in close relationship with perceptual characteristics 10. In our cases, the average F₀ was determined to be 108.9 Hz, with 57.1% of all patients having an F₀ of 110 Hz or more (Tables 2, 3).

The average F₀ has been reported to vary from 137 to 162 Hz in normal elderly men [12, 15]. Average voice in-

tensity has been determined to be 23.6 dB nHL in normal subjects (varying from 10 to 30) and has a 75–90 dB SPL (ranging from 50 to 120) [1, 11]. This decrease in I_0 is dependent upon air escape from the anterior part of the neoglottis, even though the arytenoids close completely. The lower F_0 in SRL patients results from the larger mass of the vibrating arytenoid(s) and tongue base [1, 7]. However, values of F_0 and I_0 of patients with SRL are comparable to normal elderly subjects and are adequate for understandable speech.

Averages of breathiness, hoarseness, harshness and tenseness are shown in Table 2. Breathiness was due to the free passage of escaping air through the arytenoids. Turbulence of this escaping air tended to produce hoarseness. Stiffness of vibrating structures caused harshness and tenseness [1]. As shown in Table 3, nearly all of our patients had close to normal scores.

In SRL patients, the remaining laryngeal structures have a larger mass than do normal cords. As a consequence, a stronger subglottic pressure is needed for phonation before a glottal attack. Even though the arytenoids can close completely, a large air escape from the anterior part of the neoglottis causes turbulence over the arytenoids and this tends to lead to aperiodicity, noise, reduced intensity and decreased phonatory duration. Noise is the main reason for the decrease in qualitative characteristics of the voice. However, SRL patients whose voices were rehabilitated had satisfactory phonation. Perceptual measurements of these patients were also found to be successful and similar to those of the normal elderly subjects [8, 18]. Further, verbal communication could be understood clearly. Our findings showed that reeducation resulted in improving prosodic features, correct articulation and a well-coordinated voice, with conservation of phonetic information even at a low intensity level of voice. Although a decrease was seen in F_0 and mostly in I_0 when compared to normal values, the quality and perception of speech in our patients were found to be satisfactory. While the new voice achieved after SRL appears to be less sonorous, socially acceptable speech is produced that is readily understandable for most communication needs.

Acknowledgement Grateful appreciation is given to the Turkish Petroleum Foundation (Turk Petrol Vakfı, Istanbul, Turkey) for its support of the present study.

References

1. Bless DM (1991) Measurement of vocal function. *Otolaryngol Clin North Am* 24: 1023–1033
2. Blom ED (1995) Tracheoesophageal speech. *Semin Speech Lang* 16: 191–203
3. Calearo C, Bignardi L (1986) A personal experience with subtotal and conservation as treatment for laryngeal cancer. *Arch Otorhinolaryngol* 243: 174–179
4. Calearo C, Bignardi L (1989) Laringectomy subtotale ricostruttiva: nostra esperienza (Subtotal reconstructive laryngectomy: personal experiences). *Acta Otorhinolaryngol Ital* 9: 281–295
5. Crevier-Buchman L, Laccourreye O, Weinstein G, Garcia D, Jouffre V, Brasnu D (1995) Evaluation of speech and voice following supracricoid partial laryngectomy. *J Laryngol Otol* 109: 410–413
6. Denk DM, Grasl MC, Frank F, Deutsch W, Ehrenberger K (1992) Surgical voice rehabilitation after laryngopharyngectomy: functional results of tracheo-hypopharyngeal shunts by jejunal transplantation. *Eur Arch Otorhinolaryngol* 249: 248–252
7. Ferri T, Bottazzi D, Collini M, Uberti M (1981) Logopedic rehabilitation in patients with subtotal reconstructive laryngectomy by Labayle. 68th Congress of the Italian National Society of ENT and Head and Neck Surgery, Grado, 1981
8. Formigoni P, Genovese E, Bellussi C (1985) Perceptual characteristics and quality of voice. *Acta Phoniatri Latina* 7: 270–278
9. Genovese E, Calearo C, Bignardi I (1992) Phoniatic aspects of reconstructive laryngectomy. *Rev Laryngol Otol Rhinol (Bord)* 113: 331–335
10. Hirano M (1989) Objective evaluation of the human voice: clinical aspects. *Folia Phoniatri* 41: 89–144
11. Hoasjoe DK, Martin GF, Doyle PC, Wong FS (1992) A comparative acoustic analysis of voice production by near-total laryngectomy and normal laryngeal speakers. *J Otolaryngol* 21: 39–43
12. Honjo I, Isshiki N (1980) Laryngoscopic and voice characteristics of aged persons. *Arch Otolaryngol Head Neck Surg* 106: 149–150
13. Kay MH, Hicks DM (1993) Voice pathology. In: Tucker HM (ed) *The larynx*, 2nd edn. Thieme, New York, pp 135–167
14. Laccourreye O, Crevier-Buchman L, Weinstein G, Jouffre V, Laccourreye H, Brasnu D (1995) Acoustic parameters and speech analysis after supracricoid hemilaryngopharyngectomy. *Laryngoscope* 105: 1223–1226
15. Laccourreye O, MÈrite-Drancy A, Brasnu D, Chabardes E, Cauchois R, MÈenard M, Laccourreye H (1993) Supracricoid hemilaryngopharyngectomy in selected pyriform sinus carcinoma staged as T2. *Laryngoscope* 103: 1373–1379
16. Leeper HA, Heeneman H, Reynolds C (1990) Vocal function following vertical hemilaryngectomy: a preliminary investigation. *J Otolaryngol* 19: 62–67
17. Saunders I, Wu BL, Mu L, Li Y, Biller HF (1993) The innervation of the human larynx. *Arch Otolaryngol Head Neck Surg* 119: 934–939
18. Voiers WD (1977) Diagnostic evaluation of speech intelligibility. *Acoustics* 11: 288–296