Laryngostroboscopic Evaluation After Supracricoid Partial Laryngectomy

*†Marc Makeieff, †Antoine Giovanni, and *Bernard Guerrier

**Montpellier and †Marseille, France*

Summary: *Background:* Supracricoid partial laryngectomy (SCPL) results in laryngeal preservation in more than 95% of patients with T2 glottic carcinoma. Postsurgical glottic function is characterized by an absence of vocal cords, and phonation quality is a key post-SCPL quality-of-life factor. *Objective:* This investigation was designed to enhance post-SCPL vocal function, study anatomic function of the post-SCPL larynx, and correlate anatomic findings with perceptual and instrumented measurements of voice. *Method:* Twenty-five patients were included. All had undergone SCPL with cricoepiglottopexy for T2 glottic carcinoma. All patients were evaluated by laryngostroboscopic examination, voice sample recording, and instrumented voice analysis with the aim of gaining further insight into postoperative larynx function. Laryngostroboscopic parameters such as laryngeal occlusion, epiglottic length, arytenoid movement, and vibratory area were assessed. The perceptual evaluation was based on the GRBAS scale. Acoustic and aerodynamic parameters were recorded, including fundamental frequency (F0), intensity, jitter, shimmer, signal-to-noise ratio (SNR), oral airflow (OAF), maximum phonation time (MPT), and estimated subglottic pressure (ESGP). Nonparametric tests were used to compare laryngostroboscopic parameters with instrumented measurements and perceptual evaluations of voice quality. *Results:* Correlations were established among occlusion, epiglottic length, and general grade of dysphonia. Oral air flow ($P = 0.006$) was found to be correlated with occlusion. Voice roughness was correlated with the presence of a clearly identifiable vibratory area ($P = 0.003$), whereas these vibratory areas were correlated with shimmer ($P = 0.041$), OAF ($P = 0.001$), and SNR ($P = 0.001$). The number of preserved arytenoids was not identified as a voice quality factor ($P = 0.423$). *Conclusion:* This study highlighted correlations between the laryngostroboscopic examination results and the perceptive and instrumented measurements of voice. Glottis occlusion and epiglottis length were found to be key factors for postoperative voice quality. These results should help to advance technical development on surgical techniques to enhance voice results.

Accepted for publication March 1, 2006.

From the *Service ORL Chirurgie Cervico-Faciale, Hôpital Gui de Chauliac, Université de Médecine, Montpellier, France, and †Laboratoire d'audio-phonologie clinique, Université de la Méditerranée, Marseille, France.

Address correspondence and reprint requests to Dr. Marc Makeieff, Service ORL Chirurgie Cervico-Faciale, Hôpital Gui de Chauliac, 80 avenue Augustin Fliche, 34295 Montpellier Cedex 5, France. E-mail: m-makeieff@chu-montpellier.fr

Journal of Voice, Vol. 21, No. 4, pp. 508–515
0892-1997/$32.00

doi:10.1016/j.jvoice.2006.03.001

Key Words: Multiparametric analysis—Laryngostroboscopy—Dysphonia—Supracricoid partial laryngectomy.

INTRODUCTION

Postsurgical voice quality after supracricoid partial laryngectomy (SCPL) is an important issue that can influence therapeutic decisions concerning patients with carcinoma of the vocal cords. SCPL has the advantage of offering a high oncologic control rate ($>80\%$) with the laryngeal function maintained in 95% of cases.[1,2] The voice is always modified after SCPL surgery, and the extent of dysphonia can vary markedly between patients.[3] It is currently hard to determine correlations between voice proficiency and the anatomic conformation and virtually impossible to predict how a patient's voice will perform after undergoing SCPL. Only a few studies have focused on vocal characteristics in patients after SCPL.[3–5] Supracricoid partial surgery is a key advance in the treatment of initial stage T1b and T2 glottic cancer. This surgical technique involves ablation of the entire glottic plane and cartilaginous support tissues while preserving at least one or two arytenoid cartilages that ensure laryngeal function.[2] In cases of carcinoma of the glottic plane without extension to the supraglottic area, the crico-epiglottopexy technique is used to preserve an epiglottic remnant, with only the base of the epiglottis being resected. Many studies carried out to date have focused on the carcinologic results of SCPL. It would now, however, be important to assess vocal quality after this surgery and the extent of vocal handicap. There are still many unknown phenomena concerning vocal production after SCPL. Most voice quality research is currently based on stroboscopic examination and perceptive and instrumented voice analysis, but no studies have investigated relations between instrumented measurements and laryngostroboscopic observations. Post-SCPL variability noted in instrumented measurements has still not been explained, and no correlations have been established between direct laryngostroboscopic data and more objective measurements. The aim of this study was therefore to assess relations between laryngostroboscopic findings and perceptive and instrumented measurements of voice quality with the hope of establishing precise postoperative correlations that could subsequently enable technical modifications to enhance postoperative voice quality.

MATERIAL AND METHODS

Twenty-five male patients (mean age, 59.3 years old; range, 43–72 years old) were included in this study. All patients had undergone SCPL with crico-hyoidoepiglottopexy for T2 glottic carcinoma. The time elapsed since surgery (TESS) was over 1 year in all cases. No patients had undergone postsurgical radiation therapy. The mean TESS was 4.9 years (1.9–12 years, median 4.3 years). All patients had undergone a prolonged rehabilitation period. Carcinologic assessment results were obtained for all patients at the time of evaluation. No patients had cannulation, and all had efficient swallowing function.

All patients were evaluated by laryngostroboscopic examination, voice sample recording, and instrumented voice analysis to gain further insight into postoperative larynx function. The recordings were obtained during routine postoperative evaluations in our Head and Neck Surgery Department.

Rigid endoscopes (Karl Storz, Germany) and the endo-stroboscope L system (Atmos, Germany) were used for the laryngostroboscopic examinations. Each recording was analyzed by two physicians trained on SCPL. The recordings were performed with continuous illumination and stroboscopic flashes during the phonation of a /i/ and /a/ at usual tone.

A previously described vibratory characteristics scale was used.[6] The videostroboscopic rating system was slightly modified to be suitable for the specific conformation of this partially operated larynx. The findings highlighted the presence of a mucosal vibratory area, or not, and its location. Other features assessed included the vibration regularity, the extent of glottic occlusion, the length and shape of the epiglottic remnant, and arytenoid cartilage movement. For simplicity, the results were

TABLE 1. *Laryngostroboscopic and Perceptual Evaluation Results*

Patients	Glottic Occlusion	Epiglottic Remnant Length	Epiglottic Shape	Vibratory Area Detected	Number of Arytenoids	Arytenoid Movement	Grade	Roughness
1	Complete	A	Flat	++	2	Anterior	2	2
2	Complete	U		−	2	Lateral	3	2
3	Complete	A		++	1	Anterior	2	2
4	Complete	A	Flat	++	2	Anterior	2	2
5	Incomplete	U		++	2	Anterior	3	2
6	Incomplete	A		++	2	Lateral	3	2
7	Incomplete	U		++	2	Lateral	3	2
8	Complete	A	Flat	++	1	Anterior	2	2
9	Complete	A	Flat	−	1	Lateral	2	3
10	Incomplete	U		−	2	Anterior	3	3
11	Incomplete	U		−	2	Anterior	3	3
12	Complete	A	Flat	++	2	Anterior	2	2
13	Incomplete	U		−	1	Lateral	3	2
14	Complete	U		−	2	Anterior	3	2
15	Complete	U	Flat	−	2	Lateral	3	3
16	Complete	A		−	2	Lateral	2	3
17	Incomplete	U		−	2	Lateral	2	2
18	Complete	A		++	1	Anterior	1	2
19	Incomplete	U	Flat	−	2	Anterior	2	3
20	Incomplete	U		++	1	Anterior	3	2
21	Complete	A		++	2	Anterior	2	3
22	Complete	U		−	2	Anterior	3	3
23	Complete	A		++	2	Lateral	3	1
24	Incomplete	U		−	1	Lateral	3	3
25	Complete	A		++	2	Anterior	3	2

Abbreviations: A, above the arytenoid apex; U, under the arytenoid cartilage.

noted on a binary scale: Mucosal wave vibration was classified as regular or irregular, and occlusion was complete or incomplete with respect to phonation. The epiglottic remnant was evaluated in terms of whether it exceeded the arytenoid cartilage apex. The epiglottic remnant shape was classified as plicated or not. These results are reported in Table 1.

Acoustic and aerodynamic measurements

Instrumented measurements were digitally recorded using the EVA 2^R apparatus (SQ Lab, Marseille, France), which enables simultaneous acoustic and aerodynamic measurements. This computerized speech laboratory was described in other studies.[7,8] The intensity was measured by determination of the logarithm of the efficiency value of the analogic voice signal (integration constant: 10 ms). Analog-to-digital conversion of the speech signal was performed via DT2812 acquisition (sampling rate: 6.25 kHz, 12 bits). The patients were all recorded by the same examiner in a quiet room under identical conditions. The subjects were instructed to pronounce a sustained /a/ three consecutive times for at least 3 s at a comfortable pitch and volume. Each patient was tested several times so that the examiner could select the recording that was perceptually closest to the patient's normal voice. Measurements were obtained in triplicate for each patient, and the data reported are means of the overall measurements.

The duration measurement was the maximum phonation time (MPT), ie, emission of an ''ah'' for as long as possible after taking a deep breath. Acoustic measurements were automatically obtained on a 2-s stable portion of the recorded /a/; these included the fundamental frequency (F_0) in Hertz, jitter factor (period-to-period variation in intensity) in percentage, intensity (Int) in decibels, shimmer factor (period-to-period variation in amplitude), signal-to-noise ratio in percentage

(SNR), signal-to-noise ratio $>$ 1 kHz in percentage (SNR $>$ 1), and mean oral airflow (OAF) in dm^3/second.

Subglottic pressure (ESGP) was calculated at mean intensity for the aerodynamic assessment. This pressure was estimated on the basis of the intraoral pressure when the lips came together during the phonation of /pa/ /pa/ /pa/. This method is based on the assumption that because the subglottic pressure is generated by air exiting the aerial tract during a rapid succession of plosive consonants and vowels (/pa/), then the intraoral pressure measurements immediately before the plosive /p/ can be considered as equal to the subglottal pressure when the mouth is open.[9]

Perceptual voice analysis

Voice recordings for perceptual analysis were obtained using professional-quality digital equipment (Sony TCD10 recorder; Sony Corporation, Tokyo, Japan; AKG525 microphone, AKG Acoustics, Austria). The microphone was placed 20 cm from the patient's mouth. Gain was carefully adjusted to optimize the recording dynamics. A standardized text of approximately 100 words was read as naturally as possible. The text was digitized at a sampling rate of 22050 Hz and 16 bit amplitude resolution with the *Cool Edit* software program (Adobe Audition™ Software) and transformed into a Wav audio file.

Connected speech recordings were perceptually analyzed by a jury of three physicians and two trained speech therapists who had been working for several years with patients who had undergone SCPL. Voice recordings were assessed according to G (global), R (roughness), B (breathiness), A (asthenia), and S (strain) criteria.[10,11] For each criterion and sample, the jury allocated a score ranging from 0 (normal) to 3 (severe). The samples were presented in random order and blinded with respect to the patient's identity. After listening, the jury members compared their scores and in cases of disagreement relistened to the recording until they reached a consensus.

Statistical analysis

The goal of this study was to compare perceptual scores, laryngostroboscopic evaluation, and instrumented voice measurements. The *SAS V8.2* software package (SAS Institute, Cary, NC) was used for the statistical analysis. Nonparametric tests were used because the groups studied were smaller than 30. The link between qualitative evaluations was made with a two-tailed Fisher exact test. Breathiness, asthenia, and strain were not used due to judgment variability.[12] A two-tailed Mann–Whitney U test was used to compare the laryngostroboscopic findings and acoustic parameters. For these tests, differences were considered significant when $P \leq 0.05$. When a significant difference was noted between two variables, the Bonferroni correction was used to compare the group relative with the significance threshold.

RESULTS

Laryngostroboscopic and perceptual analysis

No patients included in this study showed signs of synechia, arytenoid immobility, or laryngeal stenosis that could explain severe dysphonia. The laryngostroboscopic findings for the each patient are reported in Table 1.

Laryngeal occlusion

Laryngeal occlusion during phonation was variable after SCPL. The occlusion was classified as complete or incomplete during phonation. Ten patients (40%) were classified as having incomplete occlusion.

Vibratory area

Laryngostroboscopic evaluation identified a mucosa wave in 13 cases (52%). For other patients, during the stroboscopic examination, no distinctive vibratory area was detected. When a vibratory area was detected, in all cases, it was located at the interface between the arytenoid mucosa and the epiglottis. There was marked mucosal hypertrophy at the contact point in 7/13 patients.

Epiglottic remnant

It was easy to evaluate the epiglottic length in relation to the arytenoid apex. Two groups were constituted on the basis of the position of the epiglottic remnant, ie, above or under the arytenoid edge. The epiglottic shape was classified as flat or plicated.

Arytenoid number

One arytenoid cartilage was conserved in 9 cases and two in 14 cases. Two arytenoid cartilages were systematically conserved when permitted by the carcinological status. Arytenoid cartilage movements differed markedly depending on whether there was only one arytenoid or two arytenoids. Two types of arytenoid cartilage movement were identified: predominantly lateral movement (10 cases) and predominantly anterior movement (15 cases).

Descriptive distribution of instrumented variables

Table 2 presents the descriptive distributions of the vocal analysis variables. For each quantitative variable, the normality of the distribution was evaluated using the Shapiro–Wilk test.

Comparative analysis

Table 3 shows the *P* values obtained when the occlusion was compared with other laryngostroboscopic parameters (epiglottic length, vibratory area, and arytenoid cartilage movement). Correlations were searched using a two-tailed Fisher exact test.

Correlations between perceptual evaluation (dysphonia grade (G) roughness (R) of the GRBAS score) and laryngostroboscopic measurements are reported in Table 4. An exact Fisher test was used to correlate overall G and R of the GRBAS score to observed stroboscopic parameters. No correlations were obtained for B, A, and S GRBAS parameters so they were not included in the tables.

Correlations between instrumented measures of voice and laryngostroboscopic variables determined using Mann–Whitney Wilcoxon test are reported in Table 5. The non-parametric Mann–Whitney test results were considered significant when $P < 0.05$.

DISCUSSION

The SCPL procedure leads to major modification of the laryngeal architecture.[3] After this operation, the larynx consists of cricoid and arytenoid cartilages at least, along with an epiglottis remnant. Very little is currently known about sound production by such a modified larynx. This study is one of the first that attempts to correlate anatomic data with perceptual, acoustic, and aerodynamic measurements. Only one previous study assessed post-SCPL laryngostroboscopic data, and patients with the best acoustic characteristics (Fo, jitter, shimmer) were found to have the best symmetry and periodicity scores.[13]

Laryngostroboscopy and instrumented voice analysis are the most attractive postoperative analysis methods because they are noninvasive and produce objective quantitative data.[14] Assessment of the vocal consequences of SCPL according to the most reproducible criteria could improve comprehension of postoperative larynx function. Laryngostroboscopy allows direct visualization of the glottis,[15] but several problems arise when this technique is used after laryngeal partial surgery. The absence of an organized and constant vibratory area and complete reorganization of the laryngeal architecture hamper its use. However, it is still the main tool used in daily practice for direct observation of

TABLE 2. *Descriptive Distribution of Vocal Analysis Variables*

Parameters	Mean	SD	Min	Q25	Median	Q75	Max	Normal
F0	112.55	35.66	54.71	93.04	110.64	135.00	212.40	0.22464
Intensity	74.42	5.23	64.60	71.52	75.04	77.15	89.32	0.32545
MPT	5.810	2.483	1.522	4.032	5.367	7.500	12.404	0.50175
Jitter	6.519	4.548	0.700	2.800	5.010	8.640	19.040	0.01988
Shimmer	2.305	0.873	0.830	1.650	2.050	3.110	3.910	0.10111
ESGP	13.158	4.033	3.500	10.300	12.300	16.200	20.000	0.33349
OAF	0.390	0.216	0.086	0.230	0.347	0.574	0.899	0.12657
SNR	69.61	13.66	38.80	62.80	73.00	78.20	90.10	0.18694

Abbreviations: ESGP, estimated subglottic pressure; MPT, maximum phonation time; OAF, oral air flow; SD, standard deviation; SNR, signal-to-noise ratio.

TABLE 3. *Correlations Between Laryngostroboscopic Findings (Exact Fisher Test, P Values)*

	Epiglottic Length	Epiglottic Shape	Vibratory Area	Arytenoid Movement	Number of Arytenoids
Occlusion	0.007	0.34	0.28	0.29	0.26

the larynx. After partial laryngeal surgery, this procedure can be implemented to detect the anatomic zone responsible for mucosal wave vibration and to assess the dynamic function of the neolarynx.

The extent of arytenoid movement is directly dependent on the surgical intervention. The statics of the arytenoid cartilage are generally modified by resection of the thyro-arytenoid muscles.

When only one arytenoid cartilage remains, glottic occlusion is achieved by antero-posterior movement, and the whole arytenoid body falls forward and flattens against the epiglottic remnant. Vibration is usually detected at the contact point between the mucous membrane of the arytenoid cartilage and the epiglottis. When both arytenoid cartilages are intact, glottic occlusion is achieved by arytenoid adduction, with one arytenoid cartilage generally moving to a greater extent and overlapping the other cartilage. Hypertrophy of the mucosa of at least one arytenoid body improves occlusion. If the false vocal cords are not removed, they can complete glottic occlusion and contribute to the vibration. It is always difficult to determine exactly which vibrating structures are involved in vocal production.

The lateral and posterior crico-arytenoid muscles ensure the movement when only one arytenoid cartilage is preserved, with the lateral crico-arytenoid muscle achieving glottis closure. Contraction of this muscle ensures adduction and anterior fall of the arytenoid body. Occlusion is achieved by a shift in the arytenoid body, whose superior portion makes contact with the epiglottis, and depends on the extent of the anterior fall, the intensity of contact, the congruence of the arytenoids, and the epiglottis. The arytenoid mucosa becomes overdeveloped at the contact point during the rehabilitation period. The patient's voice can be very rough if mucosal hypertrophy has occurred. If the mucosal vibratory area is large, the sound produced is rough and deep. Four most patients, detection of an identifiable vibratory area with a marked mucosal wave was not correlated with the general dysphonia grade (G). When there were two remaining arytenoid cartilages, preservation of the inter-arytenoid muscle maintained the arytenoid bodies and limited anterior fall. Occlusion was then achieved by contact between the two arytenoid bodies and the epiglottic remnant.

TABLE 4. *Correlations Between Laryngostroboscopic Findings and Grade of Dysphonia and Roughness (Exact Fisher Test, P Values)*

	G	R
Occlusion	0.041	0.537
Epiglottic length	0.004	0.676
Vibratory area	0.237	0.003
Arytenoid movement	0.226	1.000
Number of arytenoids	0.423	0.412

Glottis occlusion is thus an important factor in neoglottic function. The position of the larynx is modified because of pexy between the cricoid cartilage and the hyoid bone. The ascending-descending movements of the larynx, shortening of the epiglottis, and modification of the false vocal cords decrease the extent of occlusion of the supraglottic part of the larynx.

After SCPL, the neolarynx does not possess vocal cords or specialized structures to enable stable and constant vibration. Glottic sound is broadcast by vibration of irregular mucosal structures located essentially at the narrowest part of the glottic zone during occlusion.

In this study, the authors found a correlation between the detected vibratory zone and voice roughness. The detected vibratory zone was also correlated with the extent of oral air flow ($P = 0.001$). When there was no evident vibratory zone, lower voice roughness was noted but there seemed to be greater glottic leak. However, a clearly recognizable vibratory zone, generally located at the top of the arytenoid body, did not modify the estimated dysphony grade ($P = 0.237$).

TABLE 5. *Correlations Between Quantitative Variables and Laryngostroboscopic Parameters (Mann–Whitney Wilcoxon Test)*

	Occlusion	Epiglottic Length	Vibratory Area	Arytenoid Movement	Arytenoid Number
F0	0.788	0.873	0.525	0.229	0.163
Intensity	0.153	0.021	0.161	0.788	0.734
MPT	0.153	0.101	0.179	0.003	0.083
Jitter	0.871	0.334	0.054	0.049	0.067
Shimmer	0.914	0.670	0.041	0.122	0.158
ESGP	0.152	0.852	0.916	0.746	0.094
OAF	0.006	0.001	0.001	0.386	0.251
SNR	0.432	0.348	0.001	0.161	0.624

The position of the epiglottic fragment had an impact on postoperative voice quality. Using the epiglottis length as a voice differentiation factor, the authors found a correlation among epiglottic length and intensity, OAF, and signal-to-noise ratio (Table 5). Several patients presenting with a small epiglottic remnant not exceeding the arytenoid apex had poor glottic closure ($P = 0.007$) and substantial glottic leak ($P = 0.001$). When the epiglottis was very small, it seemed stiff and occlusion was incomplete due to insufficient congruence with the arytenoid cartilage. Thus, support of the arytenoid cartilage on the epiglottic fragment was an important factor affecting glottic closure.

In postoperative laryngeal function, the consequences of SCPL and adaptive phenomena developed during the patient's rehabilitation to maintain voice efficiency complicate interpretation of parameter variations. Subglottic pressure and oral air flow both increase after SCPL, as confirmed in many studies.[8,16] This factor compensates for the substantial postoperative loss of air, ie, pressure increases to maintain a high stream of air necessary for mucosal structure vibration.

The laryngostroboscopic observations were compared with perceptive and instrumented analysis results, thus highlighting different correlations. Dysphonia grade was correlated with laryngeal occlusion and roughness in the presence of a clearly identified vibratory zone. Glottic occlusion was also correlated with the presence of an identifiable vibratory structure, with the length of the remaining epiglottis but not with arytenoid movement or the number of remaining arytenoids. The length of the postoperative epiglottic remnant was also found to be a postoperative voice quality factor correlated with dysphonic grade ($P = 0.004$).

When the laryngostroboscopic results were compared with the instrumented measures (Table 5), several parameters such as F0, intensity, shimmer, and signal-to-noise ratio were not directly correlated with the anatomic findings. In particular, the authors noted that global measurements such as the MPT were not influenced by glottis occlusion ($P = 0.153$). The MPT measurement concerned mobilization of the whole phonatory tract and could not be correlated with a single anatomic laryngostroboscopic parameter. Glottic occlusion was correlated with epiglottis length ($P = 0.007$) and oral airflow ($P = 0.006$), but not with the estimated subglottic pressure ($P = 0.152$). Aerodynamic phenomena such as oral air flow seemed to be important in postoperative voice quality because this factor was found to be correlated with glottic occlusion, epiglottic length, and the presence of a vibratory area.

Arytenoid movement was only correlated with MPT ($P = 0.003$) and jitter ($P = 0.049$). The presence of a clearly identifiable vibratory area seemed to be a key factor of postoperative voice roughness, and it could be correlated with shimmer ($P = 0.041$), OAF ($P = 0.001$), and the signal-to-noise ratio ($P = 0.001$). However, the vibratory conditions did not influence ESGP. One explanation is that the ESGP does not directly depend on physical conditions around the larynx,[9] and thus, it cannot be correlated with direct laryngostroboscopic results. Even if movements of the neolarynx differed markedly with the arytenoid number, it was not possible to correlate the arytenoid number with the occlusion ($P = 0.26$) or to any instrumented measurements, nor with voice quality ($P = 0.423$).

CONCLUSION

There is substantial interest in correlations between laryngostroboscopic analysis data and instrumented voice analysis results. This study highlighted correlations between laryngostroboscopic analysis data and perceptive and instrumented measurements. The aim was to gain further insight into post-SCPL laryngeal function. Glottic occlusion after SCPL and the general dysphonic grade were correlated, whereas glottis occlusion and epiglottis length were found to be important factors with respect to postoperative voice quality. According to instrumented measurements, oral air flow seemed to be an important voice quality factor. These findings should help to advance technical development on surgical techniques to improve postoperative voice quality. Further studies are needed to develop new surgical techniques to enhance occlusion of operated larynx.

REFERENCES

1. Crampette L, Garrel R, Gardiner Q, Maurice N, Mondain M, Makeieff M, et al. Modified subtotal laryngectomy with crico-hyoido-epiglottopexy—Long term results in 81 patients. *Head Neck*. 1999;21:95–103.
2. Laccourreye H, Laccourreye O, Weinstein G, Menard M, Brasnu D. Supracricoid laryngectomy with cricohyoidoepiglottopexy: a partial laryngeal procedure for glottic carcinoma. *Ann Otol Rhinol Laryngol*. 1990;99:421–426.
3. Crevier-Buchmann L, Laccourreye O, Weinstein G, Garcia D, Jouffre V, Brasnu D. Evolution of speech and voice following supracricoid partial laryngectomy. *J Laryngol Otol*. 1995;109:410–413.
4. Laccourreye O, Crevier-Buchmann L, Weinstein G, Biacabe B, Laccourreye H, Brasnu D. Duration and frequency characteristics of speech and voice following supracricoid partial laryngectomy. *Ann Otol Rhinol Laryngol*. 1995;104:516–521.
5. Zacharek MA, Pasha R, Meleca RJ, Dworkin JP, Stachler RJ, Jacobs JR, et al. Functional outcomes after supracricoid laryngectomy. *Laryngoscope*. 2001;111:1558–1564.
6. Bless DM. Assessment of vocal function. In: Ford CN, Bless DM, eds. *Phonosurgery: Assessment and Surgical Management of Voice Disorders*. New York: Raven Press; 1991:95–122.
7. Giovanni A, Estublier N, Robert D, Teston B, Zanaret M, Cannoni M. Objective evaluation of dysphonia: preliminary results of a device allowing simultaneous acoustic and aerodynamic measurements. *Folia Phoniatr Logop*. 1996;48:174–185.
8. Yu P, Ouaknine M, Revis J, Giovanni A. Objective voice analysis for dysphonic patients: a multiparametric protocol including acoustic and aerodynamic measurements. *J Voice*. 2001;15:529–542.
9. Giovanni A, Heim C, Demolin D, Triglia JM. Estimated subglottic pressure in normal and dysphonic subjects. *Ann Otol Rhinol Laryngol*. 2000;109:500–504.
10. Hirano M. *Clinical Examination of Voice*. New York: Springer-Verlag; 1981:1–98.
11. De Bolt M, Wuysts F. Test-retest study of the GRBAS scale: influence of experience and professional background on perceptual rating of voice quality. *J Voice*. 1997;11:74–80.
12. Dejonckere PH, Obbens C. Perceptual evaluation of dysphonia: reliability and relevance. *Folia Phoniatr*. 1993; 45:76–83.
13. Weinstein G, Laccourreye O, Ruiz C, Dooley P, Chalian A, Mirza N. Larynx preservation with supracricoid partial laryngectomy with cricohyoidoepiglottopexy. Correlation of videostroboscopic findings and voice parameters. *Ann Otol Rhinol Laryngol*. 2002;111:1–7.
14. Cramen B, Dejong F. Laryngostroboscopy. In: Kent RD, Bail MJ, eds. *Voice Quality Measurement*. San Diego, CA: Singular; 2000:257–268.
15. Poburka B. A new stroboscopy rating form. *J Voice*. 1999; 13:403–413.
16. Giovanni A, Guelfucci B, Yu P, Robert D, Zanaret M. Acoustic and aerodynamic measurements of speech production after near total laryngectomy with epiglottoplasty. *J Phoniatr Logop*. 2002;16:304–311.