Yonsei Medical Journal
Vol. 44, No. 6, pp. 1034 - 1039, 2003

Vocal Analysis after Vertical Partial Laryngectomy

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It is generally believed that a reconstruction of the glottic region after a vertical partial laryngectomy (VPL) can improve the glottic and supraglottic function. However, there is a paucity of reports on secondary healing without a glottic reconstruction after a VPL. The aim of this study was to obtain objective phonatory data after a VPL without a glottic reconstruction. From 1993 to 2001, 13 patients, who had been treated with VPL without a glottic reconstruction, were enrolled in this study. Patients with a postoperative follow up of less than 12 months were excluded. Seven lesions were classified as T1 glottic cancer and six as T2 glottic cancer-standard VPL (11 cases) and frontolateral VPL (2 cases). Acoustic ((fundamental frequency, Fo), jitter, shimmer, the noise to harmonic ratio (NHR)), aerodynamic (maximal phonation time (MPT), mean flow rate (MFR)) analysis and videostroboscopy were performed to evaluate the voice. There were significant differences in the Fo, jitter, shimmer, NHR, MPT and MFR between the VPL group and normal control group. In videostroboscopy, the following tendencies were observed in many cases: incomplete glottic closure, a decreased and irregular mucosal wave and amplitude, supraglottic voicing, abnormal arytenoid movement and anterior commissure blunting. Objective phonatory data after VPL without a glottic reconstruction was obtained. The voice quality after a VPL without a glottic reconstruction was somewhat unsatisfactory. A further comparison with other different surgical techniques of a VPL would help determine a better way of improving the voice quality in these patients.

Key Words: Hemilaryngectomy, vocal function

Received September 27, 2002
Accepted November 13, 2003

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INTRODUCTION

In cases of early stage T1, and T2 glottic cancer, due to the developmental and anatomical characteristics of the larynx, it is believed to be oncologically safe despite relatively narrow resection margins. As a result, numerous methods of conservation laryngeal surgery are becoming increasingly available.

After Bilroth first reported a vertical partial laryngectomy in 1875, various methods of a glottic reconstruction have been developed in order to minimize the glottic incompetence that is the cause of postoperative complications such as aspiration or voice changes. For such reconstruction, skin, pyriform sinus mucosa, sternohyoid muscle, epiglottis, free muscle, free fat, and fascia may be used.[1] Generally, a glottic reconstruction is known to be help preserve the voice. However, Hirano, et al.[2] reported that the results of postoperative vocal analysis were unsatisfactory despite the reconstruction with the hypopharyngeal mucosa, the lip mucosa, thyroid perichondrium, or skin,. Few studies have attempted to analyze the voice of vertical partial laryngectomy patients in whom a neoglottis was gained by secondary healing without a glottic reconstruction.

Therefore, in this study, acoustic, aerodynamic, and videostroboscopic measurement techniques were employed on patients who had undergone a vertical partial laryngectomy without a glottic reconstruction and were followed up for more than 1 year. The results were analyzed to observe the postoperative glottis closure, the change and appearance of the vibration, the secondary structural changes, and the compensatory mechanism of the glottis, and to investigate the causes of any voice change.

MATERIALS AND METHODS

Subjects

The subjects were chosen from early stage T1, T2 glottic cancer patients who had undergone a vertical partial laryngectomy from March, 1993 to March, 2001. The 13 patients who had their arytenoids preserved, did not undergo a glottic reconstruction, were followed up for more than one year, and vocal analysis was possible, were enrolled into this study. Patients who had undergone preoperative radiotherapy and whose follow up period was less than one year were excluded. In all 13 cases, the histological report was squamous cell carcinoma. Twelve patients were men and one was a woman. The patients' age ranged from 38 years to 74 years, with a mean age of 58.9 years, and the average follow up period was 49 months. Eleven patients were treated with a classic vertical partial laryngectomy and 2 were treated with a frontolateral vertical partial laryngectomy. The control group consisted of 12 men and 1 woman who did not have any history of pulmonary diseases, neurological diseases, or laryngeal diseases, and showed normal phonation and hearing levels on a physical examination. The age of the control group ranged from 30 years to 63 years (mean: 48.7).

Voice analysis

For the vocal analysis, the Kay company's Multi-Dimensional Voice Program (model MDVP #4305) of the Computerized Speech Lab 4300B (CSL) was used for the acoustic analysis, and Aerophone II (model AP2 #6800) of the same company was used for the aerodynamic analysis. For the acoustic tests, fundamental frequency, jitter, shimmer, and noise-to-harmonic ratio were measured. For the aerodynamic tests, the maximum phonation time (MPT) and the mean flow rate (MFR) were measured.

When using the CSL, the patients were told to say "Ah" for 3 seconds in their usual tone and volume, with their lips approximately 10 cm away from the microphone. After at least 2 attempts, the result that was chosen for the final analysis was the one closest to the normal voice. The chosen measurement was then edited to approximately one second to show the typical pattern of the 3 seconds.

When measuring the MPT, after a deep inspiration, the patients then put their face tight into the mask and said "Ah" in their usual voice tone and the volume for as long as possible for three times. Of the three measurements, the longest one was chosen for the analysis.

A Kay 70° telescope model 9150 was used for the videostroboscopy. The statistical analysis of the voice analysis measurements of the control and study group was performed by using the SAS system (version 8.1) for the t-test analysis and a p value <0.05 was considered significant.

RESULTS

Acoustic analysis

Fundamental frequency(Hz)

The average fundamental frequency (Hz) of the control and study group were 125.8 ± 18.4 Hz and 179.5 ± 50.3 Hz, respectively. There was a significant difference between the two groups (p-value: 0.0228) (Table 1).

Jitter (%)

The average jitter of the control group and study group were 0.43 ± 0.14% and 6.1 ± 4.63%, respectively. There was a significant difference between the two groups (p-value: 0.0020) (Table 1).

Shimmer (dB)

The average shimmer of the control and study group were 0.29 ± 0.21 dB and 1.33 ± 0.64 dB, respectively. There was a significant difference between the two groups (p-value: 0.0001) (Table 1).

Noise-to-harmonic ratio (dB)

The average noise-to-harmonic ratio (db) of the control and study group were 0.15 ± 0.04 dB and

0.41 ± 0.19 dB, respectively. There was a significant difference between the two groups (*p*-value: 0.0009) (Table 1).

Aerodynamic analysis

Maximum phonation time (sec)

The average maximum phonation time (sec) of the control and study group were 22.2 ± 6.93 sec and 9.39 ± 3.37 sec, respectively. There was a significant difference between the two groups (*p*-value: 0.0001) (Table 1).

Mean flow rate(L/sec)

The average mean flow rate of the control and study group were 0.18 ± 0.07 L/sec and 0.35 ± 0.18 L/sec, respectively. There was a significant difference between the two groups (*p*-value: 0.00108) (Table 1).

Videostroboscopic analysis

Incomplete glottic closure

During the vibratory cycles, 6 out of 13 subjects showed incomplete glottic closure. This was due to the decreased volume caused by the vertical partial laryngectomy and the insufficient vibration and amplitude of the neoglottis. In some cases, the incomplete glottic closure was caused by structural changes of the glottic union area (anterior commissure) and by the abnormal anteromedial movement of the arytenoids during vocal cord adduction (Fig 1).

Vibration area

In all 13 cases, although there were slight differences in the degree, the mucosal wave and amplitude were a decreased or irregular vocal cord vibration could be observed. The decrease in the mucosal wave and amplitude could be observed not only in the postoperative neoglottis, but also in the cases of a normal glottis where no surgery was performed. In five patients, in order to compensate for the incomplete glottic closure, hyperadduction of the false vocal cords, arytenoids, and vallecular fossa was observed, which contributed to the loss of voice quality. In these cases, irregular mucosal waves in the supraglottis during phonation were observed.

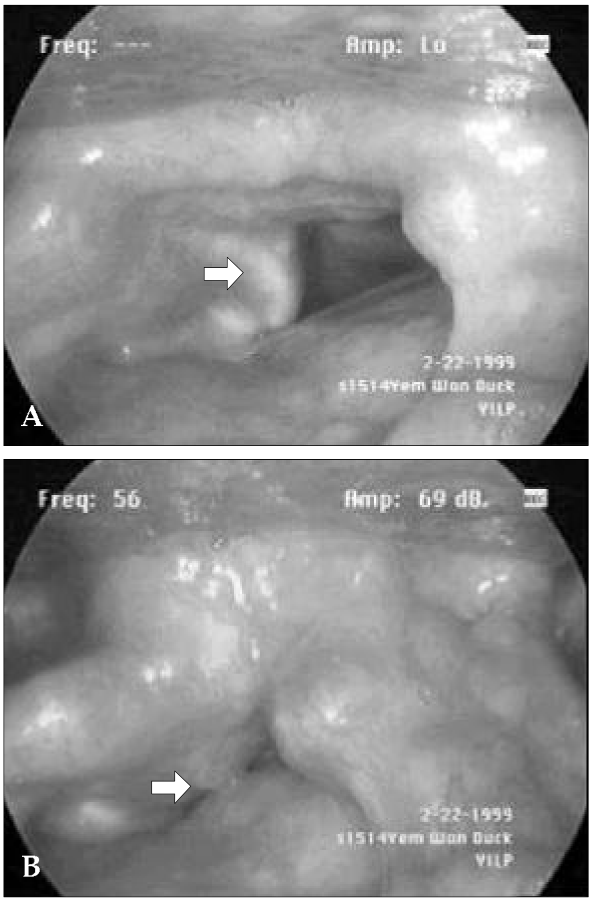

Fig. 1. Stroboscopic finding of the right post-hemilaryngectomy patient (postoperative 23 months). The white arrow indicates the neoglottis(A). Hyperadduction of the supraglottic area during vibratory cycle are noted (B).

Table 1. Acoustic and Aerodynamic Analysis of the Normal Group and Vertical Partial Laryngectomy Group

	Fo	Jitter	Shimmer	NHR	MPT	MFR
Case	179.5 ± 50.3	6.1 ± 4.64	1.33 ± 0.64	0.41 ± 0.19	9.39 ± 3.37	0.35 ± 0.18
Control	125.8 ± 18.4	0.93 ± 0.14	0.29 ± 0.21	0.15 ± 0.04	22.2 ± 6.93	0.18 ± 0.09

Fo, fundamental frequency (Hz); Jitter (%), Shimmer (dB); NHR, noise to harmonic ratio; MPT, maximal phonation time (sec); MFR, mean flow rate (L/sec).

Abnormal movement of the larynx

Abnormal movement of the healthy arytenoid to the anteromedial side was observed in 4 cases, and as previously mentioned, supraglottic hyperadduction was noted in 5 cases.

Structural changes of the larynx

Of the 2 cases of frontolateral vertical partial laryngectomy, one patient was observed to have anterior commissure blunting due to the development of postoperative granulation tissue. Therefore, the vocal cords assumed an ovoid appearance. In this case, irregular mucosal waves were observed in the supraglottis. In 4 patients, swelling and erythema were observed in the supraglottic area.

DISCUSSION

The basic function of the larynx is respiration, phonation, and protection of the lower airway. Therefore, the aim of organ preserving laryngectomy is to preserve these functions as much as possible while completely removing the laryngeal carcinoma. In other words, the objects of organ preserving laryngectomy are the prevention of aspiration and adequate phonation through glottic competence, which can be obtained by healing of the remaining tissue or by a reconstruction. In order to achieve these aims, various glottic reconstruction methods have been developed since Bilroth first reported the vertical partial laryngectomy in 1875. The first report of a glottic reconstruction was by Gluck who used a skin flap in 1903.[1] In 1917, the pyriform sinus mucosa was first used for a arytenoid replacement and this method was then modified by Som.[3] One of the most frequently used reconstruction methods after a VPL is the technique using the sternohyoid muscle and perichondrium of the thyroid cartilage, which has been modified by many surgeons.[1] The epiglottis and free tissue such as the muscle, fat tissue, and fascia can also be used for reconstruction.[1]

A glottic reconstruction is known to play an important role in glottic closure through the adduction of the vocal cord, which is a key factor in phonation. In addition, although the reconstructed area does not vibrate on its own, it is known to improve the function of the glottis and supraglottis.[1] However, although various glottic reconstruction methods exist, a method for successfully preserving the voice function after surgery has yet to be reported. In 1987, Hirano, et al.[2] reported that despite a reconstruction using the hypopharyngeal mucosa, lip mucosa, thyroid perichondrium, or skin, the results of postoperative vocal analysis were unsatisfactory. In that study, it was noted that as the time after surgery went by, the atrophy of the sternohyoid muscle flap increased. Larger muscle flaps were used to compensate for this, but the airway became narrow and problems of long time intubation developed as a result. There were also problems of necrosis of the free tissue. However, few studies have attempted to analyze the voice of the vertical partial laryngectomy patients in whom a neoglottis was gained by secondary healing without a glottic reconstruction. Only Leeper, et al.[4] investigated the vocal function of the cases of no reconstruction with secondary healing.

Patients who were treated with VPL but did not undergo a glottic reconstruction and whose arytenoid cartilages were preserved, were subjects of this study and all of the cases were followed up for more than one year. This is because, even in cases where there were no complications immediately after the surgery, structural changes and compensatory functional changes can occur as time went passes.[5] These changes influence the glottic closure and vocal cord vibration and also affected the basic form of the glottis. Therefore, a long follow up period is needed in order to accurately assess the changes after surgery.

In the acoustic analysis, the fundamental frequency of the patients was significantly higher than those of the control group. This was in contrast to reports of lower fundamental frequencies by Hirano[2] and Blaugrund.[5] In general, the fundamental frequency increases as the vibrating area is shorter, the stiffness is increased, the mass is decreased, and the subglottic pressure is increased. To date, there have been few studies that have performed a definite analysis on the fundamental frequency. Therefore, it is difficult to compare the results of this study. However, it is believed that the causes of the increase in the fundamental frequency are a shortening of the excised area, an increase in stiffness, and a decrease in mass that developed as a result of the secondary healing without a glottic reconstruction. Unfortunately, subglottic pressure, which is a major factor in the change in the fundamental frequency, was not investigated in this study. Accordingly, a future study analyzing the subglottic pressure will also be needed.

The jitter and shimmer rates were also significantly higher in the study group. However, after excluding the very high measurements of 9.6% and 8.4%, the average jitter score was greatly decreased. Jitter and shimmer generally reflect the vocal cord stability and are influenced by the asymmetry of the vocal cords, impediments in air flow, the effect of mucus on the vocal cords, and the distribution of the capillary vessels.[6] Such occurrences could be observed in the neoglottis formed after surgery on videostroboscopy, and this was believed to result in the irregular mucosal waves and the a rough voice. It is believed that these voice changes were also related to the swelling and the erythema of the vocal cords.

The noise-to-harmonic ratio was significantly higher and this was thought to be due to the increase in noise resulting from the irregular vibration of the vocal cords as well as incomplete glottic closure.[7] Another factor would be the increase in jitter and shimmer resulting in an increase in noise and a decrease in harmonics.[8]

In aerodynamic analysis, the maximum phonation time decreased significantly while the mean flow rate increased. The main reason for these changes is thought to be the incomplete glottic closure resulting from the excision of one vocal cord, and a change in the the mucosal layer and submucosal layer, which cover the vocal cord, into scar tissue. In regards to the low MPT, 3 patients were believed to have a large effect.

Laryngeal videostroboscopy is a very useful test for determining the causes of the voice changes shown in the acoustic and aerodynamic tests. It is particularly helpful in observing the structural changes and compensatory movements of the larynx after surgery. The main cause of the voice changes was believed to be an incomplete glottic closure during the vibration cycle, which was observed on videostroboscopy. Although most cases of the incomplete glottic closure were minimal, it was thought that it affected the vocal analysis measurements greatly. As Hirano reported that such incomplete glottic closure was observed in 81% of the patients who underwent a glottic reconstruction , it is difficult to conclude that aglottic reconstruction can overcome these complications. Therefore, in order to overcome a postoperative incomplete glottic closure, many comparative studies using the various methods of a glottic reconstruction, vocal hygiene, and medical treatment in similar conditions are needed. Although there were differences in the degree, the decrease in the vibration of the neoglottis and the decrease in the vibration and amplitude of the normal vocal cord also play a role in the changes in the voice parameters. It is believed that the decreases in the vibration and amplitude of the normal vocal cord was caused by the incomplete glottic closure and the swelling and erythema of the larynx. In the case where the union was not complete and an ovoid vocal cord had formed after the frontolateral vertical partial laryngectomy, laser excision was performed to remove the excessive granulation tissue, and such structural changes developed during the healing process. In 4 cases, laryngeal swelling and erythema were observed more than 1 year after surgery, and this was believed to be due to the gastroesophageal reflux seen in many laryngeal cancer patients.[9] In the cases of gastroesophageal reflux, antireflux medication decreases the laryngeal swelling and erythema and therefore improves the vocal analysis results.[9]

Patients who were treated with a vertical partial laryngectomy, showed a significant increase in the fundamental frequency, jitter, shimmer, noise-to-harmonics ratio, and mean flow rate, and a decrease in the maximum phonation time compared to the control group ($p < 0.05$). The acoustic and aerodynamic studies are an objective way of comparing the voice changes in postoperative patients. Laryngeal videostroboscopy is a useful test for determining the causes of the voice changes. In cases where more than one year has passed after the VPL was performed, incomplete glottic closure, irregular mucosal waves, a decrease in amplitude, abnormal arytenoid movements during vocal cord adduction, laryngeal swelling and erythema, and in some cases, structural changes could be observed on videostroboscopy.

The subjects of this study were patients who had undergone secondary healing without a glottic reconstruction after a VPL, and results of the voice analysis were not quite satisfactory. However, it is thought that a larger number of cases will be needed for a more precise analysis. It is also believed that various reconstruction methods should be compared using an objective and standardized procedure to determine its utility.

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