Vibratory Analysis of the Neoglottis After Surgical Intervention of Cricopharyngeal Myotomy and Implantation of Tracheal Cartilage

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Objective: To examine the effect of a new surgical intervention, consisting of cricopharyngeal myotomy and tracheal cartilaginous implantation on the anterior wall of the esophagus, for tracheoesophageal shunt and esophageal phonation.

Design: We examined the vibration of the neoglottis of tracheoesophageal shunt and esophageal speakers after total laryngectomy using a high-speed video camera (frame rate, 1000 per second).

Patients: Twenty-one alaryngeal patients were involved: 13 who had undergone the present procedure and 8 who had not.

Results: The regularity of neoglottal vibration and the degree of neoglottal closure were significantly ($P<.01$) better in patients who had undergone the procedure than in those who had not. These effects on neoglottal vibration induced easier phonation.

Conclusions: Cricopharyngeal myotomy was useful for avoiding reconstructed esophageal spasm, and tracheal cartilaginous implantation was effective for maintaining a wide subneoglottal space. This combination of procedures is useful for obtaining optimal vibration of the neoglottis in tracheoesophageal shunt and esophageal speakers.


The location of the neoglottis created during tracheoesophageal (TE) shunt or esophageal phonation after total laryngectomy is controversial. Previous studies proposed that the cricopharyngeal muscle formed the neoglottis. However, Omori et al found that 2 bulges were often observed in the pharyngoesophageal segment, using videofluorography (Figure 1). The upper bulge was considered to be created by the thyropharyngeal muscle, and the lower bulge by the cricopharyngeal muscle. Simultaneous stroboscopic findings showed that the upper bulge contributed to vibration and that this portion created the neoglottis, while the lower bulge caused obstruction of the subneoglottal space and disturbed the neoglottal vibration. Based on these findings, in 1990, we began to cut the cricopharyngeal muscle to avoid obstruction of the subneoglottal space and to implant tracheal cartilage on the anterior wall of the esophagus at the level of the cricopharyngeal muscle to maintain a wide subneoglottal space.

It was difficult to directly observe the neoglottal vibration even using stroboscopy, and aerodynamic examination has often been used to assess the vibration indirectly by measuring the intraesophageal pressure, the airflow rate, and the maximum phonation time. In this study, we directly observed the neoglottal vibration using a high-speed video camera. With this method, we examined the effects of our surgical procedure on TE shunt and esophageal phonation based on neoglottal vibration.

RESULTS

CONDITION OF THE IMPLANTED CARTILAGE AFTER SURGERY

The implanted cartilage was located just beneath the skin, and we could confirm whether the cartilage survived or was absorbed simply by palpating the implanted portion. Consequently, the survival of the implanted cartilage was verified in all patients in the implant group. The implanted cartilage caused no complication for the patients.
PATIENTS AND METHODS

SURGICAL PROCEDURE

Figure 2 shows the surgical procedure of the myotomy of the cricopharyngeal muscle and implantation of the tracheal ring cartilage. This procedure was applied for patients with laryngeal carcinoma without subglottic invasion. The upper end of the total laryngectomy was set at the suprathyroid level, and the lower end at just below the first tracheal ring cartilage. The other adjacent tissues, such as pharyngeal mucosa, were preserved. After the larynx was removed, the pharynx was closed by 2-layer sutures using a 5-0 nylon thread, making a T-shaped suture line. The thyropharyngeal muscle was sutured at its anterior portion. Myotomy of the cricopharyngeal muscle was performed at the posterior portion. A half-round cartilage was obtained from the second tracheal ring, placed on the anterior wall of the esophagus, and sutured to the wall by a 4-0 nylon thread (Figure 3). This suture should be made through the cartilage and the esophageal muscle, not through the esophageal mucosa.

Figure 4 indicates the fluorographic findings of the neoglottis during phonation 1 year after this procedure. The neoglottis was formed at the level of the thyropharyngeal muscle, and a wide subneoglottal space was observed.

PATIENTS

The patients were 21 alaryngeal patients, 13 who had undergone this procedure (implant group: male-female ratio, 10:3; mean age, 65 years; age range, 49-85 years) and 8 who had not (control group: all men; mean age, 70 years; age range, 60-78 years). The control group was selected so that the resected areas of the larynx and the suturing method of the pharynx were identical between both groups, except for myotomy and the cartilage implant. Of the implant group, 10 patients used TE shunt phonation and 3 used esophageal phonation. Of the control group, 6 used TE shunt phonation and 2 used esophageal phonation.

EXAMINATION BY HIGH-SPEED VIDEO CAMERA

The neoglottal vibration was examined using a flexible fiberscope equipped with a high-speed video camera (MEMRECAM CI/RX-1; NAC Image Technology, Tokyo, Japan). The time since the surgery to the examination ranged from 3 to 16 years (mean, 10.2 years) in the control group and from 4 months to 9 years (mean, 5.5 years) in the implant group. Videotapes were recorded during phonation of a vowel, /a/, at a frame rate of 1000 frames per second. The regularity of the neoglottal vibration and the degree of neoglottal closure were assessed. The regularity was classified into 3 groups: regular, sometimes irregular, and irregular. The neoglottal closure was also divided into 3 groups: complete, sometimes incomplete, and incomplete.

ASSESSMENT

The easiness of phonation was assessed by patient self-rating. The score was divided into 4 ranks: 0, easy to phonate; 1, moderately easy to phonate; 2, slightly difficult to phonate; and 3, difficult to phonate.

VIBRATORY PATTERN OF REPRESENTATIVE PATIENTS IN EACH GROUP

Figure 5 shows a period of neoglottal vibration of a representative patient in the cartilaginous implantation group observed by a high-speed video camera. Opening and closing phases were clearly observed. The vibration was regular, and neoglottal closure was complete.
**Figure 6** indicates a patient’s vibration in the non-implantation group. Although the mucosal wave was regular, the amplitude was small and neoglottal closure was incomplete.

**REGULARITY OF VIBRATION**

Vibration of the neoglottis was regular in 12 of 13 patients who underwent cartilaginous implantation and in 3 of 8 patients who did not. The regularity of the vibration was significantly better in the cartilaginous implantation group ($P < .01$, unpaired $t$ test) (**Figure 7**).

**NEOGLOTTAL CLOSURE**

Neoglottal closure was complete in 10 of 13 patients who underwent cartilaginous implantation and in 2 of 8 patients who did not. There was a significant difference ($P < .01$, unpaired $t$ test) between the 2 groups (**Figure 8**).

**EASINESS OF PHONATION**

The mean scores of the easiness of phonation were 0.9 in the implant group and 2.0 in the control group. There was a significant difference between the groups ($P < .01$, unpaired $t$ test).

**COMMENT**

There have been many discussions about the location of the neoglottis. The most common site previously reported was at the level of the cricopharyngeal muscle. However, Kallen noted that every fold of the mucous
membrane, every favorably placed cicatricial band, and every muscle might serve for the development of a neoglottis. Hirose\(^5\) reported that vibration was produced at the highest level of the reconstructed esophageal passage, and this portion played an important role in the articulation of consonants. According to a previous study at our institute,\(^3\) the thyropharyngeal muscle contributed to the vibration, and this site was proposed to be equivalent to the neoglottis. In contrast, contraction of the cricopharyngeal muscle caused obstruction of the sub-neoglottal space and disturbed fluent TE shunt or esophageal voice.

Singer and Blom\(^6\) examined the motion of the pharyngoesophageal segment during phonation in 16 TE shunt speakers who failed to achieve fluent speech, and found that pharyngoesophageal spasm caused the disturbance of fluent speech. To avoid this spasm, they recommended myotomy of the “pharyngeal constrictor muscle,” which is considered to be equivalent to the thyropharyngeal muscle and the cricopharyngeal muscle. According to our previous findings, however, we recommend that the cricopharyngeal muscle alone be sectioned and that the thyropharyngeal muscle be preserved because the thyropharyngeal muscle contributes to the vibration.

The cartilaginous implantation of a tracheal ring is important to maintain a wide subneoglottal space, which contributes to stable airflow and sufficient sub-neoglottal pressure during phonation. Baugh et al\(^7\) performed a preoperative assessment of “intraesophageal pressure” in patients who had undergone a laryngectomy during air insufflation before a TE shunt operation and reported that TE shunt speech fluency was better in the low preoperative intraesophageal pressure group. A TE shunt speaker may be able to phonate easily when the neoglottal mucosa vibrates with a small intraesophageal pressure, which may represent the “subneoglottal pressure.” If obstruction in the subneoglottal space occurs, excessive sub–subneoglottal pressure is needed to vibrate the

Figure 5. One period of neoglottal vibration in a representative patient in the cartilaginous implantation group; the vibration was obtained by a high-speed video camera. Complete neoglottal closure and regular vibration were observed.
Figure 6. One period of the neoglottal vibration in a patient in the nonimplantation group. Although regularity was observed, neoglottal closure was incomplete.

Figure 7. Regularity of neoglottal vibration. There was a significant difference between the 2 groups (P < .01).

Figure 8. Results of neoglottal closure during phonation. There was a significant difference between the 2 groups (P < .01).
neoglottis. Cartilaginous tracheal ring implantation may be useful to reduce the subneoglottal pressure during phonation, resulting in fluent speech.

The regularity of the neoglottal mucosa and the neoglottal closure during phonation showed better results in patients who had undergone the cartilaginous implantation with the cricopharyngeal myotomy compared with those who had not. These effects may result in easier phonation for the implanted group. We recommend the cricopharyngeal myotomy to avoid reconstructed esophageal spasm, and tracheal ring cartilaginous implantation to form a wide subneoglottal space.

Although the follow-up periods vary from 4 months to 9 years, absorption of the implanted cartilage was not observed in all patients in the implanted group. We believe that there are few problems concerning the survival of the implanted cartilage, and the effects induced by the cartilaginous implantation may continue for long periods.

In conclusion, the combination procedure of cricopharyngeal myotomy and cartilaginous tracheal ring implantation on the esophagus is useful for obtaining optimal vibration of the neoglottis in TE shunt and esophageal speakers.

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REFERENCES