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Videofluoroscopic evaluation of the swallowing function after supracricoid laryngectomy

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Abstract This study was designed to evaluate the swallowing function in patients with supracricoid laryngectomy (SCL) compared to normal subjects and to search for the factors affecting postoperative aspiration. Ten patients who underwent SCL with cricohyoidopexy (CHP) for primary laryngeal squamous cell carcinoma were included in the study. The control group consisted of 13 normal adult volunteer men with similar ages. The swallowing act of the subjects was evaluated by using videofluoroscopy (VFS) and videolaryngostroboscopy (VLS). The movements of the larynx were measured with regard to the hyoid bone, mandible and vertebral spine. The patients with SCL-CHP, except for two who had slight aspiration, had effective and near normal swallowing regarding the measurements of the movements of the hyoid bone. They could tolerate a near-normal oral diet. We have observed that the preventive precautions for aspiration are preserving the superior laryngeal nerves, suturing and positioning the crico-arytenoid unit as anterosuperiorly as possible, early decannulation and early onset of swallowing rehabilitation; the risk factors for aspiration are advanced stage of cancer, postoperative radiation and shortening of bolus transit time. VFS is useful for the patients with postoperative aspiration, because it is the definitive technique for anatomical and physiological evaluation of swallowing. We consider that the parameters of VLS and VFS, such as tongue base-arytenoid contact, presence of bolus splitting, pseudoepiglottis function, maximal opening of the pharyngoeosophageal sphincter and total movement of hyoid bone are important criteria to evaluate swallowing.

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Introduction

Supracricoid laryngectomy (SCL) with cricohyoidopexy is described as an alternative technique to total laryngectomy in selected laryngeal cancers, with similar local control and survival rates. In the last 2 decades, SCL has gained an increasing acceptance around the world [6, 15]. Cure rates approaching those of total laryngectomy can be obtained with preservation of the phonatory function of the larynx. An important result of this surgery is that a large portion of the protective structures of the upper airway is disrupted, resulting in aspiration. The patients with SCL have to learn a new swallowing act following the operation [2, 6, 14, 15].

Videofluoroscopy (VFS) is the definitive technique for studying swallowing function because it defines physiology as well as anatomy and can be viewed at reduced speeds [7, 9, 10, 12]. A few studies have been published about the swallowing act after SCL, without any control groups. This present study has been designed to evaluate the swallowing function in patients with SCL compared to normal subjects and to search for the factors affecting postoperative aspiration such as adjuvant radiotherapy, the number of arytenoid(s) preserved, movements of the larynx and tongue base, opening of pharyngoeosophageal sphincter (PES) and bolus transit time in hypopharynx.

Materials and methods

Ten patients who underwent SCL with cricohyoidopexy (CHP) for primary laryngeal squamous cell carcinoma in our Otorhinolaryngology and Head Neck Surgery Department from April 1996 to January 2002 were included into the study. All of the operations were performed by the first author. The control group consisted of 13 normal adult volunteer men at similar ages. The control subjects had no complaints of dysphagia and no history of neurological disorders or craniofacial abnormalities. Informed consent was obtained from the subjects.

The following highlights the surgical technique and postoperative swallowing rehabilitation. A standard SCL was performed on the patients. Only the critical points are summarized here. Superior laryngeal nerves were identified and preserved bilaterally. The external perichondrium of the thyroid cartilage was elevated and preserved for reconstruction. Cricopharyngeal myotomy was never performed. The pyriform sinus mucosa or tongue base were not resected in any of the patients. The base of the tongue was pulled back and downward close to the cricoarytenoid structure in order to achieve CHP. External perichondrial flaps were sutured to each other at the midline and to the anterior part of the muscles of the tongue base; thus, the cricoid unit was positioned anterosuperiorly.

The rehabilitation for swallowing began at 48–72 h postoperatively. The first exercise was to teach the patient to swallow his saliva. A semi-solid diet (potatoes mashed with milk) was given on days 3–10 postoperatively. Liquids were given as the last step. The patients who previously had undergone SCL were asked to visit and teach the hints of swallowing to the patients who were in early postoperative period. The patients were decannulated as early as 5–10 days postoperatively.

The patients with SCL were called back to the hospital for videolaryngostroboscopy (VLS) and VFS at least 6 months after surgery. The age of the patient, the duration after surgery, stage of the cancer according to AJCC 1997 [1], postoperative radiation therapy, neck dissection and the number of arytenoids preserved were recorded. The ENT examination and VLS were performed in the study and control groups. VLS was recorded on a video tape using a rigid 90° laryngeal telescope. The position(s) and movement(s) of the arytenoid(s), the contact of the tongue base to the arytenoids during phonation and the presence of pooling in the glosso-laryngeal cleft were evaluated by VLS.

VFS was performed in posteroanterior (PA) and lateral (LL) projections (25 frames per s) in all of the patients and control subjects by using the Digital Substraction Angiography Unit (Advantix LC Plus, General Electric, Paris). A 8–10-ml liquid bolus of thin barium solution was given as contrast medium. The video images were captured and recorded as avi, mpeg4 and jpeg formats on CD. Analysis of video images was performed by slow motion and frame-by-frame on a computer for evaluating the swallowing act. The captured frames (jpeg pictures) were used for measuring the distances between the mandible, hyoid bone and cervical spine. Spatial measurements were made after calibration of the digitized image to the size of a 5-cm diameter radio-opaque metal stick taped to the neck of the study subjects.

Videofluoroscopic studies were examined in detail with regard to pharyngeal handling behavior of the contrast material swallowed. This included tongue base-to-pharyngeal wall contact, splitting of the bolus on the arytenoids (on PA projection), epiglottis-like function of the tongue base on the arytenoids to channel the bolus away from the larynx (pseudoepiglottis), pooling in the tongue base-neolarynx cleft, PES opening and presence of aspiration into the trachea.

Grading of postoperative aspiration was performed according to the scale used by Leipzing and Pearson (0 = no; 1 = occasional cough but no clinical problem; 2 = constant cough worsening with meals or swallow; 3 = pulmonary complications) [4, 8].

Bolus transit time was defined as the duration in seconds from when the head of the bolus passed the level of the faucial isthmus until the peristaltic wave left the PES. Timing was done by calculating frame-by frame with a known video speed of 1/25 s per frame.

Maximal PES opening was defined as the maximal anteroposterior diameter of the PES during barium bolus passage. The elevation and anterior movement of larynx were measured with regard to the hyoid bone, mandible and vertebral spine (Fig. 1). Statistical analysis was performed using the Mann-Whitney U test. The SPSS statistical package was used.

Results

The mean age of the patients was 55.1 years (range = 47–69 years). All of the patients were male. They were decannulated successfully 5–38 days postoperatively. The control group consisted of only males, and their mean age was 57.7 years (range = 51–69 years). The parameters and measurements of the patients are presented in Table 1 for each patient.

Two of ten patients had slight aspiration (1 = occasional) according to the scale of Leipzig and Pearson. However, none of the patients had any clinical problem such as aspiration pneumonia or dietary limitations for liquids. Both of these two patients had a normal swallowing act in the first attempt for deglutition, but they aspirated during the second and additional swallowing acts. They did not aspirate the liquids when they concentrated on deglutition and did not hurry. The patients who aspirated had the shortest time for bolus transit among the study and the control groups as well. Splitting of the bolus on arytenoids was absent only in the patients with aspiration. One of the two patients with aspiration was the only patient who had postoperative radiotherapy. The tongue base did not get in contact with the arytenoids in both patients who aspirated on VLS. These patients had the lowest values of PES opening and total movement of the hyoid bone in SCL group. One arytenoid could be preserved in both of these two patients. Arytenoid movements

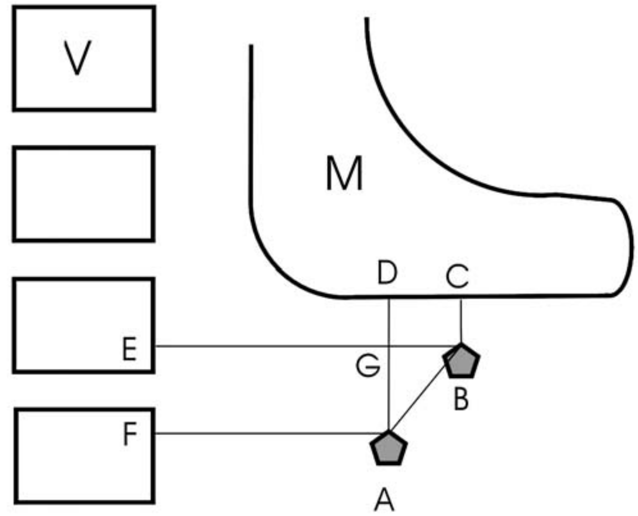

Fig. 1 Measurements of hyoid bone movement (*M* mandible, *V* vertebral column, *A* hyoid bone at rest, *B* during swallowing). Maximal hyoidomandibular distance ($|AD|$) was defined as the distance between the upper margin of the hyoid bone and lower margin of the mandible at the standing point immediately prior to swallowing, and minimal hyoidomandibular distance ($|BC|$) was defined as the shortest distance during swallowing. Maximal hyoid elevation ($|AG| = |AD| - |BC|$) was defined as the maximal cranioventral excursion of the hyoid bone measured from the standing position immediately prior to swallowing to the point of maximal cranioventral excursion during swallowing. Hyoidovertebral distance was defined as the distance between the anterior border of vertebral spine and hyoid bone at rest ($|AF|$) and during swallowing ($|BE|$). Maximal anterior movement of hyoid bone ($|GB| = |BE| - |AF|$) was defined as the maximal posteroanterior excursion of the hyoid bone measured from the standing position immediately prior to swallowing to the point of maximal posteroanterior excursion during swallowing. Total movement of hyoid bone ($|AG| + |GB|$) was defined as the addition of maximum anterior and superior movements of the hyoid bone during swallowing. Diagonal movement of hyoid bone [$|AB| = \sqrt{(|GB|^2 + |GA|^2)}$] was defined as the distance between the starting and end points of hyoid bone during swallowing

were normal in nine of the patients, and slightly impaired in one of them.

The means of the parameters of SCL and the control groups were compared in Table 2. The hyoidomandibular distances at rest and during swallowing in the study group were found to be significantly higher than the control group. These findings may suggest that the patients had an adequate elevation of the neolarynx.

The means of the parameters of the patients whose tongue base got in complete contact with the arytenoids ($n = 6$) were compared to the patients whose tongue base did not get in contact with the arytenoids ($n = 4$). Significant increases were present in total and maximal anterior movement of the hyoid bone and bolus transit time in the patients whose tongue base got in contact with the arytenoids ($P < 0.05$). This may indicate that the tongue base gets in contact with arytenoids only if the anterior and superior movements of hyoid bone are adequate.

Discussion

The swallowing act changes after partial horizontal laryngectomies such as SCL and supraglottic laryngectomy because of the new formation of the upper aerodigestive tract [6, 9, 10, 15]. The patients with SCL are under the risk of aspiration during swallowing. The patients have to learn swallowing over again and sometimes require a rehabilitation extending up to 3 months [2, 6, 15]. The swallowing function progressively improves 3–6 months postoperatively [6, 15]. We assessed the swallowing functions of the patients with SCL + CHP after a long postoperative period (mean: 38.5 months, range: 6–84 months), searched for the factors affecting swallowing and aspiration and compared this with normal subjects.

The larynx mobility is closely related to the remaining hyoid bone in horizontal laryngectomies [11], so we used the hyoid movements for evaluating the swallowing function. The hyoid bone moves superiorly and anteriorly during deglutition, the larynx enters the inferior tongue base and the airway is protected from aspiration [5]. We found no significant difference between the patients and control group in the anterior, superior, diagonal and total movements of the hyoid bone (Table 2). This result may indicate that the movements of the neoglottis are close to normal, and also a physiological swallowing act without aspiration depends on the anterosuperior movements of neolarynx and contact of tongue base to arytenoids as well. Maximal hyoid elevation was reported as 1.63 to 2.5 cm in normal subjects [3, 5]. We measured the mean of the maximal hyoid elevation as 1.92 cm in the patient group and 1.78 cm in the control group. However, Brusori reported that hyoid bone elevation was reduced after SCL with CHEP [2].

During a swallowing act following SCL, the tongue base has to approximate closely to arytenoids and also has to cover the neoglottis to protect the airway and to prevent aspiration [6, 15]. We observed that anterior and total movements of the hyoid bone were higher in the patients whose tongue base got in complete contact with the arytenoids than others ($P < 0.05$). This finding was similar to normal subjects. Tongue base-arytenoid contact has an important role in preventing aspiration, as we observed that two of four patients whose tongue base did not get in contact with the arytenoids were the ones who aspirated (Table 1). We paid attention to suture the cricoarytenoid unit as anterosuperiorly as possible; thus, we could achieve a satisfactory function of the pseudoepiglottis and prevented aspiration. At the time of the initial surgical procedures such as supraglottic laryngectomy, it may be important to position the laryngeal remnant as far superiorly and anteriorly under the tongue base as possible [10].

The patients whose tongue base got in complete contact with the arytenoids were in a lower tumor stage. This can be explained by the fact that postoperative functional results are better in the patients whose tumors

Table 1 The parameters of the patients with SCL. **1* ipsilateral modified radical neck dissection, *2* bilateral modified radical neck dissection, ***N* normal, *SI* slightly impaired

Parameters / Patients	1	2	3	4	5	6	7	8	9	10
Age	55	47	69	59	50	50	55	62	55	49
Time after surgery (months)	26	20	30	60	72	44	19	84	6	24
Stage of tumour	2	4	2	3	1	2	3	1	2	2
Adjuvant radiotherapy	No	Yes	No	No	No	No	No	No	No	No
Neck dissection*	1	2	2	1	1	2	2	2	2	2
No of arytenoids preserved	2	1	1	1	2	1	1	2	1	1
Arytenoid movements in VLS**	N	N	SI	N	N	N	N	N	N	N
Tongue base-arytenoid contact in VLS	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	No
Pooling	No	No	No	No	No	No	No	No	No	No
Bolus splitting	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pseudoepiglottis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Tongue base-pharynx contact in VFS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Aspiration	No	Yes	Yes	No	No	No	No	No	No	No
Bolus transit time (s)	0.44	0.32	0.24	0.52	0.36	0.56	0.40	0.60	0.52	0.40
Max PES opening (cm)	1.08	0.68	0.95	1.62	1.08	1.35	0.95	0.95	1.08	1.08
Max hyoid elevation (cm)	1.92	0.81	1.89	1.62	1.62	2.43	2.16	2.70	2.16	1.89
Max ant movement of hyoid bone (cm)	0.41	0.40	0.00	0.68	0.68	0.27	0.00	0.54	0.68	0.40
Total movement of hyoid bone (cm)	2.33	1.21	1.89	2.30	2.30	2.70	2.16	3.24	2.84	2.29
Diagonal movement of hyoid bone (cm)	1.96	0.91	1.89	1.76	1.76	2.44	2.16	2.75	2.26	1.93

are in an early stage because these tumors require limited resection.

The bolus splits into the right and left pyriform sinuses while it transits over the tongue base during normal swallowing. This is another mechanism that prevents aspiration. Bolus splitting was absent in only two patients who aspirated (Table 1). The contact of the tongue base with the arytenoids is important for bolus splitting. The tongue base and epiglottis split the bolus in normal subjects, while the tongue base alone splits it in the patients with SCL.

Arytenoid cartilages move to the frontomedial position, while the larynx and hyoid bone displace anterosuperiorly during swallowing; the PES opening reaches the maximum diameter, and the bolus transits to the esophagus [5]. The adequate opening of the PES has an important role for preventing aspiration, as we observed. Hyoid bone elevation is required for adequate opening of the PES [5]. We measured the mean of the PA diameter of the maximal PES opening as 1.08 and 1.10 cm in the patient and control groups, respectively ($P > 0.05$) (Table 2). The patients who aspirated had the lowest values of PES opening in the SCL group. The maximal opening of PES was reported as 0.51–0.9 cm in normal subjects [3, 5].

Bolus transit time has to be assessed for evaluating the swallowing function [3, 5, 10]. The mean of bolus transit time was reported as 0.73 s in normal subjects [3]. We found the mean of bolus transit time to be 0.44 s and 0.48 s in the study and control groups, respectively ($P < 0.05$). It is an important point that the bolus transit times of two patients with aspiration were the shortest durations among the patient and also control groups. We observed that these two patients did not aspirate when they concentrated on deglutition and did not hurry during swallowing. Vigili reported that the pharyngeal transit time was found to be 1.29 s, 1.21 s and 1.00 s in the patients with SCL, supraglottic laryngectomy and horizontal laryngectomy, respectively [12]. Schweinfurth contrarily suggested that delayed oropharyngeal transit time was a risk factor for aspiration in the patients with supraglottic laryngectomy [10]. We think that postoperative irradiation could be a predisposing factor for aspiration, because the patient who had radiotherapy was the one of two patients who aspirated.

It was reported that aspirations following SCL were generally temporary, and in grade 1 or 2, as we observed [6, 14, 15]. The presence and degree of aspiration following horizontal partial laryngectomies are related to the size of resection (pyriform recess, tongue base, hyoid bone, arytenoid cartilage), preoperative or postoperative irradiation, age of the patient and transsection of the superior laryngeal nerve [6, 7, 9, 11, 13].

In conclusion, the patients with SCL-CHP have effective and near normal swallowing regarding the measurements of the movements of the hyoid bone. They can tolerate a near-normal oral diet. We have observed that the preventive precautions for aspiration are preserving the superior laryngeal nerves, suturing and positioning the cricoarytenoid unit as anterosupe-

Table 2 Comparison of the means of the parameters of the patient and control groups

	SCL group, $n=10$ Mean ± SD Median Min-max	Control group, $n=13$ Mean ± SD Median Min-max	*P*
Age	55.10 ± 6.75 55.00 47.00–69.00	57.69 ± 5.89 56.00 51.00–69.00	0.31
Time after surgery (months)	38.5 ± 25.61 28.00 6.00–84.00	- - -	
Stage of the tumor	2..20 ± 0.92 2.00 1.00–4.00	- - -	
Max. hyoid elevation (cm)	1.92 ± 052 1.90 0.81–2.70	1.78 ± 0.72 1.78 0–2.57	0.78
Max. anterior movement of hyoid bone (cm)	0.40 ± 0.26 0.40 0–0.68	0.66 ± 0.56 0.54 0–1.89	0.31
Diagonal movement of hyoid bone (cm)	1.98 ± 0.49 1.94 0.91–2.75	1.97 ± 0.73 1.95 0.54–3.19	1.00
Total movement of hyoid bone (cm)	2.32 ± 0.55 2.30 1.21–3.24	2.43 ± 1.08 2.54 0.54–4.46	0.78
Hyoidomanibular distance during swallowing (cm)	1.02 ± 0.41 1.08 0–1.49	0.61 ± 0.79 0.41 0–2.41	0.05
Hyoidomandibular distance at rest (cm)	3.05 ± 0.58 3.01 2.16–3.97	2.05 ± 0.80 2.16 0.41–3.24	0.003
Hyoidovertebral distance during swallowing (cm)	3.81 ± 0.27 3.88 3.24–4.05	4.23 ± 0.61 4.19 3.11–5.13	0.04
Hyoidovertebral distance at rest (cm)	3.41 ± 0.26 3.46 2.97–3.65	3.61 ± 0.37 3.61 2.97–4.19	0.18
Max. PES opening (cm)	1.08 ± 0.25 1.08 0.68–1.62	1.10 ± 0.30 1.01 0.81–1.76	0.97
Bolus transit time (s)	0.44 ± 0.11 0.42 0.24–0.60	0.48 ± 0.13 0.48 0.28–0.80	0.52

riorly as possible, early decannulation and early onset of swallowing rehabilitation; the risk factors for aspiration are advanced stage of cancer, postoperative radiation and shortening of bolus transit time.

VFS is useful for patients with postoperative aspiration, because it is the definitive technique for anatomical and physiological evaluation of swallowing. We consider that the parameters of VLS and VFS, such as tongue base-arytenoid contact, presence of bolus splitting, pseudoepiglottis function, maximal PES opening and total movement of the hyoid bone, are important criteria to evaluate swallowing.

References

1. AJCC (1997) American Joint Committee on Cancer: AJCC cancer staging manual, 5th edn. Lippincott-Raven, Philadelphia, pp 40–46
2. Brusori S, Soro A, Tesci F, Mattioli S, Calculli L, Marchi M, Mazza C, Gavelli G (1998) Deglutition in patients treated with reconstructive laryngectomy. Radiol Med (Torino) 95:154–160
3. Bülow M, Olsson R, Ekberg O (1999) Videomanometric analysis of supraglottic swallow, effortful swallow and chin tuck in healthy volunteers. Dysphagia 14:67–72
4. Leipzig B (1980) Neoglottic reconstruction following total laryngectomy: a reappraisal. Ann Otol Rhinol Laryngol 89:534–537
5. Leonard RJ, Kendall KA, McKenzie S, Gonçalves MI, Walker A (2000) Structural displacements in normal swallowing: a videofluoroscopic study. Dysphagia 15:146–152
6. Naudo P, Laccourreye O, Weinstein G, Hans S, Laccourreye H, Brasnu D (1997) Functional outcome and prognosis factors after supracricoid partial laryngectomy with cricohyoidopexy. Ann Otol Rhinol Laryngol 106:291–296
7. Oeken J, Hansch U, Thiel S, Bootz F (2001) Swallowing function after endoscopic resection of supraglottic carcinoma with the carbon dioxide laser. Eur Arch Otorhinolaryngol 258:250–254
8. Pearson BW (1981) Subtotal laryngectomy. Laryngoscope 91:1904–1912

9. Prgomet D, Bumber Z, Bilic M, Svoren E, Katic V, Poje G (2002) Videofluoroscopy of the swallowing act after partial supraglottic laryngectomy by CO_2 laser. Eur Arch Otorhinolaryngol 259:399–403
10. Schweinfurth JM, Silver SM (2000). Patterns of swallowing after supraglottic laryngectomy. Laryngoscope 110:1266–1270
11. Strek P, Lorens K, Reron E, Modrzejewski M, Skladzien J, Szybist N, Belowska J, Kitlinski Z (2000) Manometric evaluation of disorders in oral and pharyngeal phases of swallowing in patients after partial layngectomy for localized supraglottic cancer (abstract). Otolaryngol Pol 54:709–715
12. Vigili MG, Colacci AC, Magrini M, Cerro P, Marzetti A (2002) Quality of life after conservative laryngeal surgery: a multidimensional method of evaluation. Eur Arch Otorhinolaryngol 259:1–16
13. Wasserman T, Murry T, Johnson JT, Myers EN (2001) Management of swallowing in supraglottic and extended supraglottic laryngectomy patients. Head Neck 23:1043–1048
14. Woisard V, Puech M, Yardeni E, SerranoE, Pessey JJ (1996) Deglutition after supracricoid laryngectomy: compensatory mechanisms and sequelae. Dysphagia 11:265–269
15. Zacharek MA, Pasha R, Meleca RJ, Dworkin JP, Stachler RJ, Jacobs JR, Marks SC, Garfield I (2001) Functional outcomes after supracricoid laryngectomy. Laryngoscope 111:1558–1564