Oral Radiology (2019) 35:230–238
https://doi.org/10.1007/s11282-018-0341-0

ORIGINAL ARTICLE

Swallowing function in advanced tongue cancer patients before and after bilateral neck dissection following superselective intra-arterial chemoradiotherapy for organ preservation: a case-control study

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Received: 25 May 2018 / Accepted: 30 July 2018 / Published online: 20 August 2018

Abstract

Objective This study aimed to evaluate swallowing function in advanced tongue cancer patients before and after bilateral neck dissection following superselective intra-arterial chemoradiotherapy (CRT).

Methods A videofluoroscopic swallowing study (VFSS) was used to evaluate swallowing function in 10 patients with advanced tongue cancer before and after bilateral neck dissection.

Results Laryngeal penetration increased in the postoperative VFSS. Temporal analysis comparing two time points revealed that, after surgery, oral transit time increased significantly, but there was no difference in pharyngeal delay time or pharyngeal transit time. Spatial analysis revealed significant decreases after surgery in the maximum distance of upper esophageal sphincter (UES) opening, the maximum distance of hyoid bone movement in both the anterior and superior direction, and the maximum velocity of hyoid bone movement.

Conclusions Laryngeal penetration and aspiration increased as a result of limited hyoid movement and diminished UES opening after bilateral neck dissection following superselective intra-arterial CRT for advanced tongue cancer.

Keywords Swallowing function · Advanced tongue cancer · Bilateral neck dissection · Hyoid bone · Superselective intra-arterial chemoradiotherapy

Introduction

The standard treatment for advanced tongue cancer is radical surgery that includes extensive glossectomy, neck dissection (ND), and microsurgical reconstruction. Postoperatively, patients may experience dysphagia caused by impaired bolus transport in the oral cavity and/or impaired pharyngeal contraction in the laryngopharynx. Because extensive glossectomy and ND are risk factors for dysphagia in tongue cancer patients [1], chemoradiotherapy (CRT) including superselective intra-arterial CRT has recently been applied to avoid radical surgery for primary cancer [2–4]. Patients with cervical lymph node metastasis often undergo planned ND after CRT. Although many studies have evaluated swallowing function after unilateral ND, fewer have evaluated it after bilateral ND following CRT for advanced tongue cancer. Against this background, this study evaluated differences in swallowing function in advanced tongue cancer patients before and after bilateral ND following superselective intra-arterial CRT for organ preservation. Specifically, we used a videofluoroscopic swallowing study (VFSS) to focus on temporal analysis of bolus movement and spatial analysis of the upper esophageal sphincter (UES) and hyoid bone.

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Materials and methods

This study was reviewed and approved by the Institutional Review Board of our university (No. B150601016). Written informed consent to use imaging data was obtained from patients. The case-control study was conducted according to the Declaration of Helsinki.

Patients

Imaging data were analyzed for 10 patients (5 men and 5 women; mean age, 48.4 years; age range 26–67 years) with advanced tongue cancer who underwent retrograde superselective intra-arterial CRT followed by planned bilateral ND in our department between April 2010 and June 2016 (Table 1).

Treatment

The retrograde superselective intra-arterial CRT was performed as follows. Catheterization from the superficial temporal artery and/or the occipital artery was performed. In the case of a tumor lesion that involved the contralateral side beyond the median line, another catheter was inserted in the contralateral side for bilateral arterial injection. The tip of the catheter was selectively inserted in the lingual artery and the facial artery. After catheterization, the perfusion area of the anticancer agent was confirmed by digital subtraction angiography and angio-computed tomography (CT). The angio-CT was performed with slow infusion via a catheter to determine whether the anticancer agents delivered via arterial infusion permeated the entire tumor. During the treatment period, the patients were injected with indigotindisulfonate sodium more than once per week to confirm that the anticancer agent fully perfused the tumor. The anticancer agent was injected in a bolus over 1 h through the catheter during the irradiation. The dose of docetaxel was 10 mg/m^2/week, for a total of 60–70 mg/m^2 during the whole treatment course, and that of cisplatin (CDDP) was 5 mg/m^2/day, for a total of 150–175 mg/m^2. Sodium thiosulfate, a CDDP-neutralizing agent, was also administered intravenously at 1 g/m^2 immediately after arterial infusion of CDDP. Treatment planning for X-ray irradiation (XRT) was based on three-dimensional CT images taken at 2-mm intervals. The gross tumor volume (GTV) was determined by CT, magnetic resonance imaging (MRI), and positron emission tomography (PET)/CT scans prior to treatment. Clinical target volume (CTV) was defined as GTV plus a 5-mm margin. Planning target volume (PTV) was basically defined as CTV plus a 5-mm margin, but it could be finely adjusted where necessary to take into account organs at risk. The daily XRT fraction was 2 Gy using a 6-MV linear accelerator (Clinac iX; Varian Medical Systems, Palo Alto, CA, USA), and the XRT schedule was 60–70 Gy in 30–35 fractions delivered over 6–7 weeks (conventional technique). For patients with cervical lymph node metastases, the XRT field was set up to cover the primary tumors and the ipsilateral (levels I–IV for N1) or bilateral (levels I–V for N2) cervical lymph node areas, including lymph node metastases as the CTV. After a total dose of 40 Gy had been delivered to the initial field, an additional 20–30 Gy was delivered to the primary tumors and metastatic lymph nodes within the shrunken field. About 2 months after CRT, the patients underwent planned bilateral ND for cervical lymph node metastasis.

Table 1 Characteristics of advanced tongue cancer patients in this study

Case no.	Age (years)	Sex	Stage	Radiation dose
1	58	M	III	60 Gy
2	38	F	IVA	66 Gy
3	56	F	III	70 Gy
4	67	F	IVA	60 Gy
5	64	M	IVA	60 Gy
6	44	M	III	66 Gy
7	44	M	IVB	70 Gy
8	44	F	IVA	70 Gy
9	43	F	IVA	70 Gy
10	26	M	IVB	70 Gy

F female, *M* male

Objective swallowing assessment

We evaluated swallowing function using VFSS data taken in all patients at two time points: 1 week before bilateral ND and 2 weeks after bilateral ND. Because the first time point was 2 months after completion of the retrograde superselective intra-arterial CRT and the acute effect of the CRT was relieved, the VFSS was performed 1 week before bilateral ND as a preoperative assessment. The second VFSS was performed to judge whether oral intake was possible or not at 2 weeks after bilateral ND. The VFSS was performed with a lateral projection using a fluoroscope (Medites CREA; Hitachi Co. Ltd., Tokyo, Japan). To calibrate the image, we attached an 11 mm-diameter metal ball to the midline of the patient's chin. The patient was in a seated position during the examination. A 3-ml bolus of swallowing agent (50% w/v barium sulfate, adjusted to the viscosity of a nectar-liquid with mixed thickener) was injected into the oral cavity at the floor of mouth and was held in the mouth until a cue was given to swallow it. The examination was performed twice without changes to posture or swallowing technique. The VFSS image was recorded on a digital video recorder at 30 frames per second. The image data were then imported into a personal computer and saved as AVI format movie files. Quantitative analysis was performed using two image analysis software packages, DIPP-Motion V 2D (Ditect Co. Ltd., Tokyo, Japan) and ImageJ 1.48v (http://imagej.nih.gov/ij/). As measurement items for clinical, temporal, and spatial analysis, we selected oral transit time (OTT); pharyngeal delay time (PDT); pharyngeal transit time (PTT); movement patterns of the bolus and oropharyngeal structures in the oral preparatory, oral, pharyngeal, and cervical esophageal phases of swallowing; laryngeal penetration; and the approximate amount and cause of any aspiration that could be evaluated from the lateral view of the oral cavity and pharynx [5].

Clinical analysis: Laryngeal penetration, aspiration, and pharyngeal residue

To evaluate laryngeal penetration (passage of material into the larynx but not below the vocal folds) and aspiration (passage of material below the level of the vocal folds), we used the 8-point Penetration-Aspiration Scale (PAS) previously described by Rosenbek et al. [6]. We assessed VFSS images in real time, slow motion, and frame by frame. PAS scores of 2–5 and 6–8 were defined as laryngeal penetration and aspiration, respectively. Because normal patients without dysphagia sometimes had penetration above the vocal folds with clearance from the laryngeal vestibule, a PAS score of 2 was used as the normal cutoff, and a score of ≥ 3 was considered abnormal. We also considered the type of ND and suprahyoid muscle resection. Rodemaker et al. [7] used assessment of oropharyngeal swallowing efficiency and quantitative assessment of pharyngeal residue. We evaluated only the presence or absence of pharyngeal residue; the amounts of pharyngeal residue and aspiration were measured by eye and were subject to errors by the evaluator. We evaluated pharyngeal residue with or without a bolus at the base of tongue, the epiglottic vallecula, and the pyriform fossa after each swallowing trial, because it was thought that pharyngeal residue may be one of the factors related to aspiration [8].

Temporal analysis

The tip of the bolus was tracked by slow playback and frame-by-frame analysis using DIPP-Motion V 2D to determine the timing of (a) tongue movement initiation in the oral stage of swallowing, (b) the bolus head reaching the point where the lower border of the mandible crosses the tongue base, (c) laryngeal elevation in the pharyngeal stage of swallowing, and (d) the bolus tail passing through the cricopharyngeal region (pharyngoesophageal segment). OTT, PDT, and PTT were defined as (b)–(a), (c)–(b), and (d)–(b), respectively.

Spatial analysis

Maximum distance of the UES opening

We identified the UES as the point along the esophagus that had the narrowest anterior-posterior diameter. We then determined the maximal distance of the UES as the bolus passed between the levels of the third and sixth cervical vertebrae (C3–C6; Fig. 1) using image analysis software (ImageJ 1.48v). We measured the UES opening because it can affect aspiration [8].

Two-dimensional motion analysis of hyoid bone movement

The risk of aspiration is high when the distance of hyoid bone movement is small, and delay in the movement velocity of the hyoid bone can affect aspiration because the hyoid bone moves rapidly anterosuperiorly [9, 10]. We measured the movement of the hyoid bone for kinematic and spatial analysis. Two-dimensional motion analysis was performed using the DIPP-Motion V 2D cineradiography system. Digital motion data were transformed into actual diameters using the distance from the reference metal ball. On the VFSS

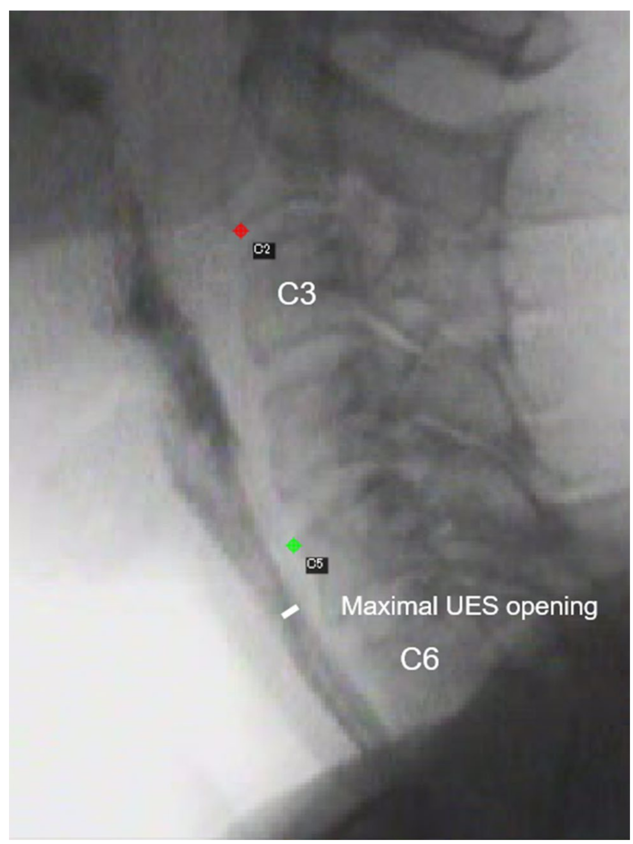

Fig. 1 Maximum anterior-posterior diameter of the upper esophageal sphincter (UES) opening. White line indicates the UES diameter. C3, third cervical vertebra; C6, sixth cervical vertebra

lateral images, the most superior point along the anterior aspect of the fifth cervical vertebra (C5) was set as point A, the most inferior point along the anterior aspect of the second cervical vertebra (C2) as point B, and the most anterior point of the hyoid bone as point C (Fig. 2). Point A was defined as the origin; the line from point A to point B as the *y*-axis; and the line orthogonal to the *y*-axis at point A as the *x*-axis. Two-dimensional calibration was performed frame by frame. The following variables were measured: (1) maximum anterior-posterior movement (mm) of the hyoid bone (point C) along the *x*-axis; (2) maximum superior-inferior movement (mm) of the hyoid bone (point C) along the *y*-axis; and (3) maximum velocity (mm/s) of the hyoid bone (point C) in the anterosuperior direction. Maximum movement of the hyoid bone was defined as the distance between the highest and lowest points that the bone reached during swallowing [11]. We calculated the velocity of the hyoid bone movement using the distance between two adjacent time points (1/30 s) throughout the swallowing cycle. We also calculated the mean velocity using the distance the hyoid bone moved in the last 5 frames divided by 5/30 s, to reduce measurement error [9].

Statistical analysis

The Mann–Whitney *U* test was used to compare OTT, PDT, and PTT before and after bilateral ND. Student's *t* test was used to compare values for the following before and after ND: maximum distance of the UES opening, maximum anterior-posterior movement of the hyoid bone (along the *x*-axis), and maximum velocity of the hyoid bone in the anterosuperior direction. Welch's *t* test was used to compare maximum superior-inferior movement of the hyoid bone (along the *y*-axis) before and after bilateral ND. All statistical analysis was performed using SPSS Statistics for Windows (IBM Japan Ltd., Tokyo, Japan). Statistical significance was set at $P < 0.05$.

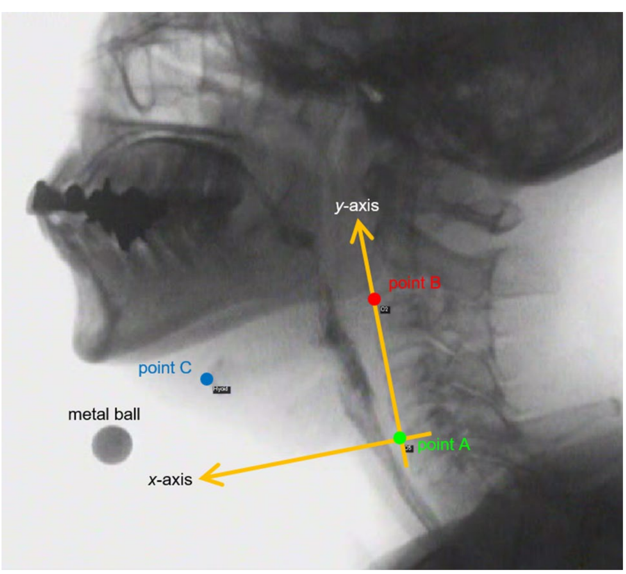

Fig. 2 Anatomical points of reference and axes used in the analysis of hyoid bone movement. Point A (green) is at the superior limit of the anterior aspect of the fifth cervical vertebra (C5); point B (red) is at the inferior limit of the anterior aspect of the second cervical vertebra (C2); point C is the hyoid bone; *y*-axis, the line passing through points A and B; *x*-axis, the line orthogonal to the *y*-axis at point A

Results

Clinical analysis

Before surgery, a VFSS showed that 20% of patients had laryngeal penetration but none had aspiration. After surgery, 60 and 20% of patients had laryngeal penetration and aspiration, respectively. Abnormal PAS scores (i.e., ≥ 3) were noted in 10% of patients before surgery and 70% after surgery (Table 2). Types of ND and suprahyoid muscle resection are shown in Table 2. Suprahyoid muscle resection during bilateral ND was not associated with postoperative aspiration. There was pharyngeal residue in 40% of patients before surgery and 80% after surgery (Table 2).

Temporal analysis

The results of temporal analysis before and after bilateral ND are shown in Table 3. Before and after surgery, median OTT was 1.44 and 1.93 s, respectively, median PDT was 0.00 and 0.15 s, respectively, and median PTT was 0.72 and 0.77 s, respectively. The only temporal parameter that increased significantly after surgery was OTT.

Spatial analysis

The results of spatial analysis before and after bilateral ND are shown in Table 4. All parameters decreased significantly after surgery: maximum distance of the UES opening decreased by 23.9%; maximum anterior-posterior movement of the hyoid bone decreased by 36.0%; maximum superior-inferior movement of the hyoid bone decreased by 30.1%; and maximum velocity of the hyoid bone in the anterosuperior direction decreased by 34.4%.

Discussion

Postoperative dysphagia in oral cancer patients is caused by extensive tissue loss, limited excursion of the remaining tissue, and sensory paralysis of the tongue, soft palate, and pharynx [12]. Because such patients have difficulties

Table 2 Swallowing function and type of neck dissection in advanced tongue cancer patients

Case no.	PAS score		Pharyngeal residue		Neck dissection type	Suprahyoid muscle resection
	Preoperative	Postoperative	Preoperative	Postoperative		
1	1	3	+	+	RND + MRND	Ipsilateral PBDM and SHM
2	2	3	+	+	RND + MRND	–
3	1	2	–	–	RND + MRND	Ipsilateral PBDM and SHM
4	1	1	–	–	RND + SOHND	Ipsilateral PBDM
5	1	8	+	+	MRND + MRND	–
6	1	3	–	+	RND + MRND	–
7	1	1	+	+	MRND + SOHND	–
8	1	3	–	+	MRND + SOHND	–
9	1	8	–	+	RND + MRND	–
10	3	3	–	+	RND + MRND	Ipsilateral PBDM and SHM

MRND modified radical neck dissection, *PAS* penetration-aspiration scale, *PBDM* posterior belly of digastric muscle, *RND* radical neck dissection, *SHM* stylohyoid muscle, *SOHND* supraomohyoid neck dissection

Table 3 Temporal analysis before and after bilateral neck dissection

	Preoperative	Postoperative	*P* value
Oral transit time (s)	1.44 (0.78–2.10)	1.93 (0.15–3.71)	0.033
Pharyngeal delay time (s)	0.00 (– 0.22 to 0.22)	0.15 (– 0.36–0.66)	0.260
Pharyngeal transit time (s)	0.72 (0.54–0.90)	0.77 (0.19–1.35)	0.329

Table 4 Spatial analysis of swallowing before and after bilateral neck dissection

	Preoperative	Postoperative	Decrease rate (%)	*P* value
Maximum distance of UES opening	4.6 ± 1.5 mm	3.5 ± 1.7 mm	23.9	< 0.001
Maximum anterior-posterior movement of hyoid bone along *x*-axis	13.9 ± 3.2 mm	8.4 ± 2.1 mm	36.0	< 0.001
Maximum superior-inferior movement of hyoid bone along *y*-axis	18.6 ± 6.5 mm	13.0 ± 3.6 mm	30.1	0.002
Maximum velocity of hyoid bone in anterosuperior direction	51.7 ± 17.0 mm/s	33.9 ± 11.1 mm/s	34.4	< 0.001

in the pharyngeal stage of swallowing in addition to the oral stage, CRT has been performed as organ preservation therapy. Swallowing motility disorders after CRT include reduced anterior-posterior tongue movement, reduced tongue strength, reduced tongue base retraction, increased oral residue, increased velopharyngeal closure duration, reduced epiglottic inversion, slowed or reduced laryngeal elevation, impaired pharyngeal constrictor motility, increased pharyngeal residue, delayed pharyngeal swallow, and delayed laryngeal vestibule closure [13]. Even after CRT is performed for organ preservation, swallowing function is not maintained at normal levels because radiation-induced fibrosis of the irradiated structures results in limited mobility of the tongue, tongue base, pharynx, and larynx [13]. The incidence of post-treatment aspiration has been variously reported between 5 and 89%, with silent aspiration between 22 and 42% [13]. Dysphagia after CRT is a potentially serious complication that can be life-threatening. Although there are many studies of swallowing function in advanced tongue cancer patients after radical surgery, few studies have evaluated swallowing function after ND in tongue cancer patients without post-treatment symptoms associated with the oral stage of swallowing [8]. Therefore, we focused here on swallowing function in advanced tongue cancer patients before and after bilateral ND following superselective intra-arterial CRT for organ preservation.

Previous temporal analysis focusing on bolus movement in healthy subjects revealed OTT was 1.0–1.5 s, PDT ≤ 0.7 s, and PTT ≤ 1.0 s [5]. OTT increases slightly when bolus viscosity increases, and OTT in elderly people increases more than in non-elderly adults [5]. Compared with healthy subjects in the present study, OTT was not extended before surgery, but was extended after surgery. The reason for this could be that there was little possibility that any influence of the retrograde superselective intra-arterial CRT remained. The significant prolongation in postoperative OTT is thought to result from disorders in the oral preparatory and oral phase of swallowing caused by restriction of tongue mobility resulting from edema of the oropharyngeal area after bilateral ND. In terms of PDT and PTT, Kotz et al. [14] reported no significant prolongation of PDT or PTT after CRT in advanced head and neck cancer patients. To reduce swallowing disorders/aspiration in patients undergoing radiotherapy for head and neck cancer, Rancati et al. [15] reported minimizing the volume of the pharyngeal constrictors and larynx receiving < 60 Gy and reducing, when possible, the volume receiving < 50 Gy. In the present study, it was thought that PDT and PTT before surgery were not prolonged because the radiation dose was 40–50 Gy and anticancer agents were not administered to the hypopharyngeal and laryngeal region in the retrograde superselective intra-arterial CRT. Hirai et al. [8] reported no increase in PTT after unilateral ND in oral cancer patients who did not have postoperative symptoms in the oral stage of swallowing. The present study also found no significant increase in PDT or PTT after surgery, with both parameters within the limits found in healthy subjects. Our findings reveal that bilateral ND 2 months after CRT does not affect PDT or PTT in patients who do not have a delayed swallowing reflex or delayed bolus transfer in the pharyngeal stage of swallowing.

Many studies have performed spatial analysis of swallowing using VFSS images, often with a focus on hyoid bone movement and structural changes around the laryngopharynx. In the present study, we analyzed the two-dimensional kinematic movement of the hyoid bone that indicates initiation of the pharyngeal stage of swallowing and UES opening following this movement. In normal subjects, hyoid bone movement is caused by contraction of the suprahyoid and thyrohyoid muscles, which initiates superior laryngeal movement, producing anterior traction on the cricoid and contraction of the thyrohyoid muscle. This series of muscular contractions and movements is thought to open the UES [16, 17]. In particular, we should consider the anterior and superior movements of the hyoid bone. The former is related to age and the volume of the bolus being swallowed [10, 18, 19]. The latter is related to closure and protection of the laryngeal vestibule and traction of the cricopharyngeal muscles at the time of UES opening [20, 21]. Reduced hyoid bone elevation and laryngeal movement indicate a swallowing impairment, with features such as impaired bolus transport, abnormal UES opening, and aspiration [22, 23]. Therefore, analyzing the movement of the hyoid bone on VFSS images is important to understanding the etiology of dysphagia in the pharyngeal stage.

Generally, the maximum diameter of the UES opening is thought to depend on the volume of the bolus. Maximum UES opening distance was reported to be 5.1 ± 1.5 mm when healthy subjects swallowed a 3-ml bolus of liquid and 5.9 ± 1.3 mm when patients with early stage oral cancer swallowed a 4-ml bolus of liquid 1 month after unilateral ND [8, 24]. In our study, the distance was 3.5 ± 1.7 mm with a 3-ml bolus 2 weeks after bilateral ND following CRT. This postoperative UES distance was significantly less than the preoperative UES distance (4.6 ± 1.5 mm; $P < 0.001$) and was less than that of healthy subjects and patients with unilateral ND. This postoperative decrease in the maximum distance of the UES opening could be caused by restricted anterosuperior movement of the hyoid bone after partial resection of the suprahyoid muscles and restricted anterior traction forces on the UES. Healthy subjects show anterosuperior movement of the hyoid bone and relaxation of the cricopharyngeal muscles, resulting in normal enlargement of the UES. The bolus normally passes through the UES, and pharyngeal residue after swallowing is barely detectable. In the present study, the abnormal enlargement of the UES caused by limited hyoid bone movement led to increased pharyngeal residue and decreased pharyngeal clearance, which can easily lead to aspiration.

The velocity of hyoid bone movement also affects aspiration [25], and a decrease in this velocity leads to delayed closure of the laryngeal vestibule and increases the risk of aspiration. Maximum velocity increases depending on the volume of the bolus and the maximum movement of the hyoid bone [9]. In healthy subjects, the maximum velocity of the hyoid bone in the anterosuperior direction was reported to be 49.9 ± 9.3 mm/s when swallowing a 2.5-ml bolus of liquid [9]. In the present study, maximum velocity was significantly decreased after bilateral ND following CRT (51.7 ± 17.0 mm/s preoperative vs. 33.9 ± 11.1 mm/s postoperative; $P < 0.001$). This decreased velocity leads to delayed closure of the laryngeal vestibule, resulting in penetration and aspiration. Accordingly, an abnormal PAS score (i.e., ≥ 3) occurred more often after surgery than before it (10% preoperative vs. 60% postoperative). Generally, during swallowing, the hyoid bone of healthy subjects moves markedly in a posterosuperior direction, and then mainly in an anterosuperior direction. It then follows the same pathway to return to its original position. However, in most patients who have had bilateral ND, the hyoid bone follows an irregular pathway with a small amount of movement and frequent swallowing. Instability of the hyoid bone position may be an obstacle to laryngeal movement and may lead to an increase in pharyngeal residue and failed opening of the esophagus entrance.

Graner et al. [26] evaluated swallowing function before and 5 months after intra-arterial CRT for advanced pharyngeal and laryngeal cancer. The 11 patients received 72 Gy to the primary tumor and 54 Gy to the diseased nodes. Seven of all 11 patients who underwent planned ND (5 unilateral ND and 2 bilateral ND) 6 weeks after intra-arterial CRT had significantly worse laryngeal elevation than the 4 patients who did not undergo ND. Furthermore, tongue base retraction and laryngeal penetration were worse after treatment. Son et al. [1] reported that patients who underwent modified radical ND had a higher incidence of aspiration than those who underwent supraomohyoid ND. Although there are few studies of swallowing function after ND in patients without reconstruction, Hirai et al. [8] evaluated swallowing function after unilateral ND (Level I–V) in patients with early stage oral cancer. The incidence of penetration increased by 5.9% after surgery, but no aspiration was observed and there were no serious clinical problems. In contrast, in the present study, after bilateral ND, the incidence of penetration and aspiration increased by 40% and 20%, respectively. This difference in the incidence of dysphagia is a result of preservation of oropharyngeal and hypopharyngeal function on the healthy side in unilateral ND.

To mitigate the risk of dysphagia after bilateral ND following CRT for advanced tongue cancer, several methods have been considered, including administration of a reduced radiation dose to the primary tumor and neck, prophylactic muscle exercises, laryngeal suspension, observation without ND, and/or ND of a limited area. The radiation field is related to the primary tumor site and size and to the nodal tumor bulk. As Kumar et al. [27] pointed out, radiation dose to the larynx and pharyngeal constrictor muscles has been the focus of efforts to understand and ameliorate dysphagia caused by radiotherapy, but the suprahyoid muscles and the muscles of the floor of the mouth are critical for hyoid bone and laryngeal elevation, effective bolus diversion, and preventing penetration and aspiration [27]. Radiation dose to the floor of the mouth and the geniohyoid muscle may be associated with an increased risk of laryngeal penetration and aspiration to a greater degree than previously recognized; specifically, they found that radiation dose to the geniohyoid muscle rather than the pharyngeal constrictor muscle was more closely related to PAS score [27]. Advances in radiation delivery—such as intensity modulated radiation therapy [28] or proton beam therapy [4], where the uninvolved constrictor musculature is spared high-dose radiation—may lessen tissue fibrosis that increases the risk of a poor swallowing outcome and thus lessens the effect of post-radiotherapy ND. Furthermore, these advances in radiation delivery can preserve salivary flow and reduce xerostomia [13].

Prophylactic swallowing exercises can preserve swallowing function in post-CRT patients with head and neck cancer [13, 29–31]. A randomized trial showed that swallowing exercises are associated with early improvement in swallowing function after CRT [31]. Because prophylactic muscle exercises during CRT can improve thyroid muscle shortening, UES opening, and hyoid bone movement, they may successfully prevent acute dysphagia [29]. The Shaker Exercise, an isometric and isokinetic head lift exercise performed in the supine position three times a day for 6 weeks [32], can augment thyrohyoid muscle shortening as well as strengthen the suprahyoid muscles [32]. Thus, the exercise can increase UES opening and anterior excursion of the larynx and hyoid bone during swallowing in patients with UES dysfunction, resolving aspiration and allowing resumption of oral intake [32]. Range motion exercises of the tongue and jaw during radiotherapy may help prevent trismus, reduce the formation of fibrotic tissue, and improve pharyngeal clearance by maintaining adequate contact between the tongue base and pharyngeal wall [13].

Superselective intra-arterial chemotherapy for primary tongue cancer has a therapeutic effect on subclinical metastatic sentinel lymph nodes because the intra-arterially injected anticancer agent passes via lymph flow into sentinel lymph nodes [33–35]. According to Minamiyama et al. [35], superselective intra-arterial chemotherapy for tongue cancer can control occult neck metastasis by reaching sentinel lymph nodes and perfusing the neck (levels I–IIA) from the lingual and facial artery. Although the incidence of occult neck metastasis in T3–4 tongue cancer is between 50 and 58% [35], unnecessary prophylactic (supraomohyoid) ND can be avoided by superselective intra-arterial chemotherapy combined with radiotherapy, resulting in only unilateral ND with less impact on swallowing function.

A recent review showed that planned ND after CRT for head and neck cancer could be avoided in cases of clinical complete nodal response diagnosed by follow-up imaging modalities such as PET [36]. However, radiologically node-positive cases or nodal recurrence cases must undergo ND after CRT. Therefore, superselective ND (limited to pre-CRT positive nodal levels) or selective ND may preserve swallowing function after CRT with bilateral ND. Furthermore, swallowing function after CRT may be improved by laryngeal suspension with cricopharyngeal myotomy [37, 38] during ND. This is supported by the study of Fujimoto et al. [38] showing that 88.6% of patients with advanced oral or oropharyngeal cancer who underwent bilateral ND with laryngeal suspension and cricopharyngeal myotomy could achieve oral intake without tube feeding.

This study has several limitations, such as the retrospective design and the small number of included patients. In this retrospective study, we could not evaluate late swallowing function in advanced tongue cancer patients after bilateral ND following superselective intra-arterial CRT for organ preservation. Additionally, there are fewer advanced tongue cancer patients who have had to undergo bilateral ND after CRT than patients who have undergone only ipsilateral ND. Therefore, a prospective long-term study is required to evaluate the late swallowing function. Although this study provided only two-dimensional analysis, further clarification of detailed swallowing kinematics could be obtained with the use of three-dimensional analysis using dynamic CT such as 320-detector-row multislice CT [39].

In conclusion, bilateral ND following superselective intra-arterial CRT in advanced tongue cancer patients led to an increased incidence of laryngeal penetration and aspiration. These swallowing problems could be explained by the reduced hyoid movement and UES opening. Although further study is necessary, postoperative dysphagia may be improved by prophylactic muscle exercise, reduced radiation dose to the primary tumor and neck, observation without ND, limited ND area, and/or laryngeal suspension with cricopharyngeal myotomy during ND.

Compliance with ethical standards

Conflict of interest Nobuhide Ohashi, Toshinori Iwai, Haruka Tohara, Yumi Chiba, Senri Oguri, Toshiyuki Koizumi, Kenji Mitsudo, and Iwai Tohnai declare that they have no conflict of interest.

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