The Laryngoscope

Sonographic Assessment of Swallowing in Irradiated Nasopharyngeal Carcinoma Patients

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Objectives/Hypothesis: Ultrasonography is an emerging clinical tool to study the dysfunction of swallowing muscles. This was the first sonographic study to assess the relationship between suprahyoid muscle contraction, hyoid bone displacement, and penetration-aspiration status (PAS) during swallowing in nasopharyngeal carcinoma (NPC) patients treated with radiotherapy (RT). The study also aimed to establish reliability data for the sonographic technique described.

Study Design: Cross-sectional study.

Methods: Geniohyoid muscle contraction was quantified using brightness-mode ultrasonography in this study of 40 post-RT NPC patients. A series of physiological parameters and PAS were measured using videofluoroscopy.

Results: Intra- and inter-rater agreement values ranged from 0.75 to 0.96 across various sonographic measurements. Percentage increase in the cross-sectional area of the geniohyoid muscle correlated with anterior ($r = 0.42$, $P < .05$) but not superior ($r = 0.27$, $P = .09$) hyoid displacement. Anterior hyoid displacement and pharyngeal constriction ratio were significantly associated with PAS score.

Conclusions: Sonographic measurement of suprahyoid muscles provides valuable information on muscle function and is potentially a useful clinical tool in swallowing assessment. Further research is needed to refine the role of this examination in dysphagia.

Key Words: Dysphagia, nasopharyngeal carcinoma, ultrasonography, suprahyoid muscles, hyoid bone.

Level of Evidence: 2b.

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INTRODUCTION

Nasopharyngeal carcinoma (NPC) is the most common head and neck cancer in Hong Kong.[1] The primary modality of treatment for NPC is radiotherapy (RT), which can result in progressive dysphagia over time.[2] Patients treated for NPC represent a considerable proportion of the dysphagia caseload managed by speech therapists in local Hong Kong hospitals.

Post-RT dysphagia is often caused by dysfunction of the swallowing muscles. Of the various muscle groups involved in swallowing, the suprahyoid group of muscles play an important role in swallowing. This group includes the geniohyoid, mylohyoid, digastric, and stylohyoid, and is responsible for moving the hyoid bone, which then causes other physiological changes during swallowing. These changes include 1) upper esophageal sphincter (UES) opening, which allows pharyngeal clearance of the bolus into the esophagus,[3] and 2) laryngeal vestibule closure and epiglottic retroflexion, which are important for airway protection.

In a cadaver model study,[4] the geniohyoid was found to be the major suprahyoid muscle responsible for the anterior displacement of the hyoid bone. In another physiological study using functional magnetic resonance imaging (MRI),[5] the geniohyoid was also found to be the most active muscle during hyolaryngeal elevation in terms of effect size change in the T2 signal. Due to possible muscle damage by radiation, the anterior hyoid displacement in irradiated NPC patients was found to be significantly reduced compared to healthy individuals.[6] As a possible consequence, more stasis was seen in the pyriform sinuses in these patients, increasing the chance of overflow aspiration.

Dysphagia can be evaluated by instrumental examinations. Videofluoroscopic study of swallowing (VFSS) has traditionally been the gold standard of instrumental swallowing examination. Most physiological impairment during the oral and pharyngeal phase can be visualized and measured with the use of an oral contrast medium and radiation. In Hong Kong, however, an instrumental swallowing examination is not part of the routine evaluation for patients referred for dysphagia due to limited manpower, with only a small portion of dysphagic patients undergoing an instrumental examination. Compared to VFSS, swallowing examination using ultrasonography (USG) involves less manpower and time. Speech therapists, with adequate

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training, can independently perform a dysphagia-related ultrasound examination, which can easily be conducted in their clinic and completed in a short period of time. In addition, USG is more available in certain clinical settings due to its higher portability and lower costs. It can be repeated on a regular basis, as it brings no discomfort or harm to patients. USG is, therefore, a potentially important swallowing assessment tool that has the capacity of providing supplementary information including muscle function.

The application of ultrasonography in the assessment of swallowing, nonetheless, has been limited. It is becoming increasingly popular in dysphagia research since its principles and application as a swallowing examination were described in detail.[7–9] With USG, the movement of various swallowing structures, as well as certain muscles, can be visualized and studied in detail. Early swallowing research with USG was mainly conducted on normal populations with the goal of establishing technical procedures and normative data for different age groups and genders.[10,11] Macrae et al. recently described a novel method of measuring hyoid bone displacement using midsagittal brightness-mode (B-mode) ultrasonography, and concluded that intra- and inter-rater reliabilities were good.[12] The technique was subsequently used to measure hyoid bone movement in 52 dysphagic patients with mixed neurological diagnoses, where a significantly greater hyoid bone movement was found in the nonaspirator group.[13] Hsiao et al. measured the change in tongue thickness and hyoid bone displacement during swallowing in 60 stroke and 30 healthy subjects.[14] Both parameters were found to be significantly less in the tube-fed patient group. Sonographic studies of head and neck cancer populations focused more on post-RT muscle changes. Watkin et al. measured the cross-sectional area (CSA) of the geniohyoid muscle in a small sample of normal subjects versus head and neck cancer patients.[15] The irradiated patients exhibited a significantly larger geniohyoid CSA at rest, probably due to the decomposition of collagen and fibrotic tissue. To date, no sonographic study has been conducted to look at suprahyoid muscle activity and suprahyoid-hyoid relationship in patients with dysphagia.

The present study aimed to 1) use USG to quantify the contraction of the geniohyoid muscle during swallowing, 2) assess the relationship between geniohyoid muscle contraction and hyoid bone displacement during swallowing, and 3) determine the effect of geniohyoid muscle contraction, in addition to a series of physiological swallowing parameters, on the penetration-aspiration status of post-RT NPC patients. By establishing such relationships, preliminary information would be available regarding the potential of USG as a routine swallowing screening and monitoring tool for post-RT head and neck cancer patients.

MATERIALS AND METHODS

Participants

Forty post-RT NPC patients were recruited from the ear, nose, and throat (ENT) outpatient clinic of the Prince of Wales Hospital in Hong Kong. Demographic and treatment information was collected (Table I). There were 31 male and nine female participants, with a mean age of 53.9 years. The average number of years since the completion of treatment was 9.7 years. Treated NPC patients were invited to participate if 1) they had undergone a complete course of radiotherapy or chemoradiotherapy, and their detailed treatment record was available for review; 2) a minimum of 3 years had elapsed since the completion of radiotherapy; and 3) they were over 18 years of age at the time of recruitment. Patients were excluded if they had 1) metastatic disease, 2) any tumour recurrence, 3) a history of neurological disease prior to the diagnosis of NPC, 4) a history of dysphagia prior to the diagnosis of NPC, 5) a history of surgery to the head and neck region, and 6) been tube fed or tracheostomized. Written consent was obtained prior to data collection. The study was approved by the Joint Chinese University of Hong Kong–New Territories East Cluster Clinical Research Ethics Committee.

TABLE I.
Demographic and Treatment Information of the Participants.

Demographic/Treatment Information	No.	%
Gender		
Male	31	77.5
Female	9	22.5
Age, yr (mean = 53.9 years)		
21–30	2	5
31–40	3	7.5
41–50	8	20
51–60	16	40
61–70	8	20
71–80	3	7.5
Stage of disease (UICC/AJCC 7th Edition, 2009)		
I	9	22.5
II	11	27.5
III	12	30
IV	8	20
Radiation technique		
Conventional radiotherapy	18	45
Intensity-modulated radiotherapy	22	55
Radiation dose		
$<$70 Gy	25	62.5
$\geq$70 Gy	15	37.5
Use of chemotherapy		
Yes	20	50
No	20	50
No. of years postirradiation (mean = 9.7 years)		
3–5	7	17.5
6–10	19	47.5
11–15	9	22.5
16–20	4	10
21–25	1	2.5

UICC/AJCC = Union for International Cancer Control/American Joint Committee on Cancer.

Brightness-Mode Ultrasonography

The contraction of the geniohyoid muscle during swallowing was estimated using B-mode submental ultrasonography. A

Fig. 1. (Left) A portable diagnostic ultrasound machine for the measurement of geniohyoid activity. (Right) Coronal placement of a linear ultrasound transducer in the submental region.

B-mode ultrasound image is a cross-sectional image that shows tissue or organ boundaries. The brightness of the image at each point is dependent on the strength of the ultrasound echoes.[16] A Mindray M7 (Mindray, Shenzhen, China) portable diagnostic ultrasound system (Fig. 1, left) and a 6 to 14 MHz linear transducer (Fig. 1, right) were used. All ultrasound examinations were carried out by a speech therapist with 8 years of clinical experience in dysphagia management (D.T.H.C.). Prior training on knowledge and technical skills in acquiring B-mode submental images was provided by a consultant radiologist and a senior sonographer. The quality of the acquired images and the identification of key structures were verified by the sonographer.

Each participant was instructed to sit upright, relax, and keep the head in a neutral position throughout the examination. A layer of conductive gel was applied to the transducer, which was then placed in coronal orientation in the submental region and just above the hyoid bone as illustrated in Figure 1 (right). A real-time image displaying an outline of the suprahyoid muscles is shown in Figure 2 (top). The participant was then instructed to swallow 5 mL of water at room temperature from a standard spoon in one swallow action. Throughout the swallow trial, the position of the transducer was adjusted in an anteroposterior manner to follow the movement of the hyoid bone and was kept just above the hyoid bone. Pressure exerted by the transducer on the submental region was kept to a minimum to avoid distortion of the muscles being examined. The swallow trial was repeated twice to obtain a set of three measurements. All swallows were video recorded at 16 frames per second.

The contraction of the geniohyoid muscle was estimated by measuring the percentage increase in coronal CSA. Ultrasound recordings of each swallow were played back frame by frame. The frame prior to the geniohyoid muscle starting to thicken in response to a swallow was selected to measure its CSA at rest (CSA_{rest}) (Fig. 2, top), whereas the frame, in which the geniohyoid exhibited maximum thickness during a swallow, was chosen to measure its maximum CSA (CSA_{max}) (Fig. 2, bottom). If there were multiple swallows per bolus, the first swallow was used for analysis. CSA_{rest} and CSA_{max} were manually outlined and calculated using the built-in function. The percentage increase in CSA for each swallow was subsequently calculated with the following formula: percentage increase in CSA of geniohyoid = (CSA_{max} − CSA_{rest}) / CSA_{rest}. The three values of each participant were averaged to obtain a final value. A higher percentage increase in CSA represented a larger degree of muscle contraction.

Videofluoroscopic Study of Swallowing

Videofluoroscopy was conducted to obtain a series of physiological measurements. A Siemens Artis Zee Multi-purpose System (Siemens, Erlangen, Germany) was used. The examinations were digitally recorded using a Sony DVD Recorder DVO-1000MD (Sony, Tokyo, Japan). All images were acquired at 30 frames per second. As a reference of magnification, a 6-cm

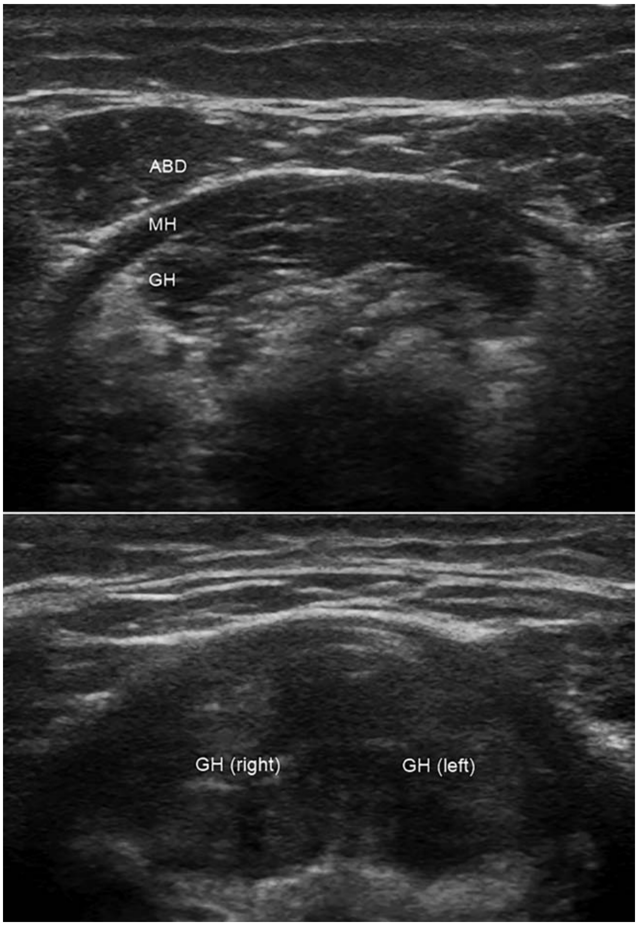

Fig. 2. Brightness-mode submental image in coronal view of the suprahyoid muscles at rest (top) and during maximum contraction (bottom). ABD = anterior belly of digastric; GH = geniohyoid; MH = mylohyoid.

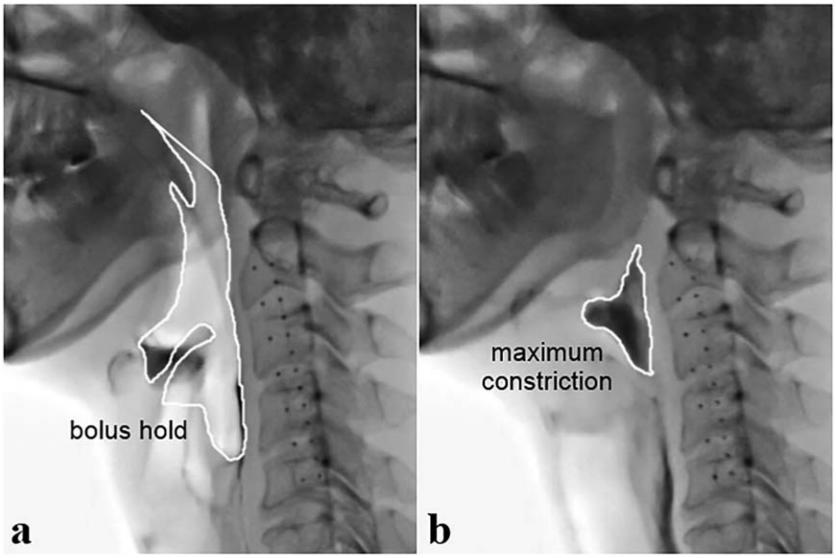

Fig. 3. Anatomical boundaries for tracing the pharyngeal area at (a) preswallow hold position, and (b) maximum constriction for the calculation of the pharyngeal constriction ratio during a thin liquid swallow. The ratio is 25% in this example.

calibration ruler was taped to the participant's lateral neck along the cervical spine and on the side closer to the pulse generator. Food materials were premixed with E-Z-HD Barium Sulfate for Suspension (96% w/w) (E-Z-EM Canada Inc., Anjou, Quebec, Canada) according to a standard concentration formula. All examinations were carried out by speech therapists experienced in VFSS. The participant was instructed to swallow 5 mL of water mixed with barium at room temperature from a standard spoon and to swallow it in one swallow action. The participant was reminded to maintain a constant head position throughout the examination. If there were multiple swallows per bolus, the first swallow was used for analysis. The swallow trial was repeated twice to obtain a set of three measurements, which were averaged to obtain a final value. Frame-by-frame analysis of the following temporal and kinematic parameters was conducted. Pixel-based measurement was performed using the ImageJ digital image analysis software (National Institutes of Health, Bethesda, MD).

Oral transit time. The time interval is in seconds from the onset of lingual movement propelling the bolus posteriorly until the bolus head passes the ramus of the mandible.

Pharyngeal transit time. The time interval is in seconds from the time the bolus head passes the ramus of the mandible until the bolus tail passes through the cricopharyngeal sphincter.

Pharyngeal delay time. The time interval is in seconds from the time the bolus head passes the ramus of the mandible until the onset of laryngeal elevation.

Duration of laryngeal vestibule closure. The time interval is in seconds during which the laryngeal entrance between the arytenoid and the base of the epiglottis is closed.[17]

Pharyngeal constriction ratio. Pharyngeal constriction ratio (PCR) is the ratio of pharyngeal area (in square centimeters) at maximum constriction of a swallow divided by that at the preswallow hold position. The PCR has been shown to correlate inversely with manometric measurements of pharyngeal pressure during swallowing.[18,19] A higher percentage indicates a weaker pharyngeal constriction. The procedures described and anatomical definition given by Kendall et al. were adopted to select reference frames (i.e., preswallow hold position and maximum pharyngeal constriction) and outline the boundaries of the respective areas for the calculation of the PCR (Fig. 3).[20]

Anterior and superior hyoid movement. To measure hyoid bone displacement (in centimeters), an x-y coordinate system was produced on the videofluoroscopic image in such a way that the y-axis passed through the most anteroinferior point of the cervical vertebrae C2 and C4, whereas the x-axis intersected perpendicularly with the y-axis and the origin located at the most anteroinferior point of C4 (Fig. 4).[21] The image was then rotated so that the y-axis became vertical. Maximum anterior and superior hyoid displacement were selected independently (Fig. 4a,b), whereas the rest frame was defined as the frame in which the hyoid bone returned to its lowest position after each swallow (Fig. 4c).

Maximum UES opening. The maximum UES opening was the anteroposterior distance (in centimeters) of the bolus column at the narrowest section between cervical vertebrae C3 and C6, measured on the frame of maximum distension during swallowing.[22]

The penetration-aspiration status (PAS) of each swallow was scored from videofluoroscopic images using the Penetration-Aspiration Scale.[23] If the score differed among the three swallow trials, the highest score was chosen. Swallowing outcome was categorized as 'no penetration-aspiration' (i.e., PAS <3) and 'penetration-aspiration present' (i.e., PAS ≥ 3). Functional swallowing performance was rated using the Dysphagia Outcome and Severity Scale (DOSS) score[24] during videofluoroscopic evaluation involving thin, thick, paste, soft solid, and solid consistencies.

Statistical Analysis

All statistical analyses were performed with IBM SPSS Statistics, Version 22.0 (IBM Corp., Armonk, NY). To assess intrarater reliability of sonographic and videofluoroscopic measurements, the first author reperformed the same measurements on 50% of all subjects, and the results obtained from the two independent measurements were compared. To determine interrater reliability, a second rater performed the same measurements on 50% of all subjects, and the results obtained from the two independent raters were compared. Reliabilities were analyzed using the intraclass correlation coefficient (ICC). A two-way mixed single measures model and an absolute agreement definition were employed.

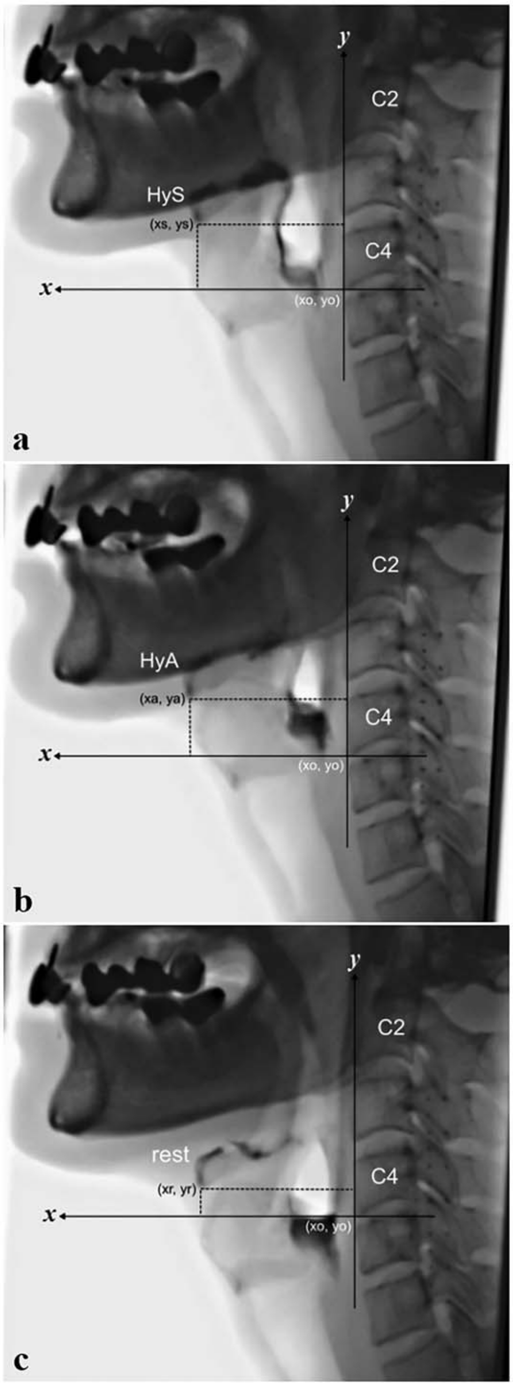

Fig. 4. Measurement of hyoid displacement on rotated images. An x-y coordinate system was constructed with reference to C2 and C4. The hyoid position was measured at its (a) maximum superior displacement (Hy_S), (b) maximum anterior displacement (Hy_A), and (c) lowest position postswallow.

The relationship between geniohyoid muscle contraction and hyoid bone displacement was assessed using the Pearson correlation coefficient. Logistic regression analysis was employed to identify significant physiological variables that increased the risk of dysphagia when controlling for other variables. All eight videofluoroscopic variables were included, and those with $P < .05$ in univariate analyses were selected and entered into the multivariate regression analysis, where a stepwise method was used. The level of significance was set at .05 for all analyses.

RESULTS

Physiological and Functional Swallowing Data

Aspiration of thin consistency was seen in seven patients (17.5%), whereas 24 patients (60%) did not demonstrate penetration or aspiration with this consistency. Nonoral nutrition was recommended in three patients (7.5%). Sonographic and videofluoroscopic measurements, PAS score for thin fluid, and DOSS score of the 40 patients are summarized in Table II.

Reliability Data

The reliability data of sonographic and videofluoroscopic measurements are presented in Table III. Reliability values were excellent. Single-measures ICC values for intrarater agreement was 0.95 for CSA_{rest} measure, 0.96 for CSA_{max} measure, and 0.76 for percentage increase in CSA. Single-measures ICC values for inter-rater agreement was 0.91 for CSA_{rest} measure, 0.89 for CSA_{max} measure, and 0.75 for percentage increase in CSA. Single-measures ICC values for all videofluoroscopic measures ranged from 0.89 to 0.96 for intrarater reliability, and from 0.87 to 0.91 for inter-rater reliability.

TABLE II.
Physiological and Functional Swallowing Measurements of the 40 Patients.

Physiological Parameter		Mean (SD)	Range
USG	% increase in GH CSA (%)	46 (19)	14 to 74
VFSS	OTT, s	1.08 (0.43)	0.56 to 2.34
	PTT, s	1.20 (0.62)	0.62 to 3.14
	PDT, s	0.08 (0.32)	−0.61 to 1.04
	DLVC, s	1.05 (0.35)	0.31 to 2.10
	PCR, %	15 (10)	2 to 40
	Hy_A, cm	0.91 (0.28)	0.45 to 1.68
	Hy_S, cm	1.23 (0.44)	0.40 to 2.18
	UES_M, cm	0.46 (0.18)	0.12 to 0.87
		No.	%
PAS score	1–2 (normal)	24	60
	3–5 (penetration)	9	22.5
	6–8 (aspiration)	7	17.5
DOSS score	1–2 (nonoral nutrition)	3	7.5
	3–5 (full PO modified diet)	14	35
	6–7 (full PO normal diet)	23	57.5

CSA = cross-sectional area; DLVC = duration of laryngeal vestibule closure; DOSS = Dysphagia Outcome and Severity Scale; GH = geniohyoid; Hy_A = anterior hyoid displacement; Hy_S = superior hyoid displacement; OTT = oral transit time; PAS = Penetration Aspiration Scale; PCR = pharyngeal constriction ratio; PDT = pharyngeal delay time; PO = per oral; PTT = pharyngeal transit time; SD = standard deviation; UES_M = maximum upper esophageal sphincter opening; USG = ultrasonography; VFSS = videofluoroscopic study of swallowing.

TABLE III.
Intrarater and Inter-rater Reliability Statistics of Sonographic and Videofluoroscopic Measurement.

Measurement	ICC (3, 1)	95% CI	*P* Value
Intrarater agreement			
Sonographic measurement			
CSA_{rest}	0.95	0.91 to 0.97	<.001
CSA_{max}	0.96	0.93 to 0.98	<.001
% increase in CSA of GH	0.76	0.62 to 0.85	<.001
Videofluoroscopic measurement			
OTT	0.89	0.71 to 0.95	<.001
PTT	0.89	0.73 to 0.96	<.001
PDT	0.91	0.77 to 0.96	<.001
DLVC	0.91	0.78 to 0.97	<.001
PCR	0.92	0.81 to 0.96	<.001
Hy_A	0.95	0.87 to 0.98	<.001
Hy_S	0.96	0.89 to 0.98	<.001
UES_M	0.94	0.86 to 0.98	<.001
Inter-rater agreement			
Sonographic measurement			
CSA_{rest}	0.91	0.86 to 0.95	<.001
CSA_{max}	0.89	0.80 to 0.94	<.001
% increase in CSA of GH	0.75	0.61 to 0.84	<.001
Videofluoroscopic measurement			
OTT	0.89	0.55 to 0.97	<.001
PTT	0.88	0.72 to 0.95	<.001
PDT	0.87	0.70 to 0.95	<.001
DLVC	0.90	0.77 to 0.96	<.001
PCR	0.90	0.76 to 0.96	<.001
Hy_A	0.88	0.71 to 0.95	<.001
Hy_S	0.88	0.54 to 0.96	<.001
UES_M	0.91	0.77 to 0.96	<.001

CI = confidence interval; CSA = cross-sectional area; DLVC = duration of laryngeal vestibule closure; GH = geniohyoid; Hy_A = anterior hyoid displacement; Hy_S = superior hyoid displacement; ICC = Intraclass correlation; OTT = oral transit time; PCR = pharyngeal constriction ratio; PDT = pharyngeal delay time; PTT = pharyngeal transit time; UES_M = maximum upper esophageal sphincter opening.

Relationship Between Geniohyoid Contraction and Hyoid Displacement

The percentage increase in CSA of the geniohyoid muscle correlated with anterior hyoid displacement, with a Pearson correlation coefficient of 0.42 (P = .008) (Fig. 5, top), whereas it did not correlate with superior hyoid displacement (r = 0.27, P = .09). Treatment-related variables including radiation technique (P = .12), radiation dose (P = .20), use of chemotherapy (P = .08), and number of years since treatment (P = .36) were not associated with the degree of geniohyoid contraction.

Relationship Between Physiological Parameters and Penetration-Aspiration

The stepwise logistic regression model identified anterior hyoid displacement (B = −3.962, P = .022) and pharyngeal constriction ratio (B = 0.611, P = .015) as being significantly associated with the risk of penetration-aspiration while controlling for the presence of each other and the remaining independent variables (Table IV). Boxplots of anterior hyoid displacement and pharyngeal constriction ratio against PAS score are shown in Figure 5 (bottom left and bottom right).

DISCUSSION

This study on the relationship between suprahyoid muscle activity as visualized on USG and hyoid bone movement as observed on videofluoroscopy in post-RT NPC patients is the first, to the best of our knowledge. Results suggest a significant positive correlation between the percentage increase in CSA of the geniohyoid muscle and the anterior movement of the hyoid bone during thin-fluid swallows. It would seem logical that increasing degrees of muscle contraction correlated with larger anterior hyoid displacement. This finding lends clinical support to findings from previous cadaveric and human studies,[5,6] in which the geniohyoid muscle was found to be an important suprahyoid muscle responsible for the anterior projection of the hyoid bone.

To understand the role of anterior hyoid displacement in swallowing safety, we included a number of other physiological variables in a regression. The model revealed a significant association between anterior hyoid movement and the occurrence of penetration-aspiration in thin-fluid swallows. One physiological explanation would be that such movement is associated with the opening of the UES, a movement important for pharyngeal clearance of food boluses.[3] Inadequate pharyngeal clearance results in pooling of food residue in the pyriform sinuses, increasing the likelihood of eventual overflow aspiration.[25]

The major purpose of employing ultrasonography in this study was to quantify the contraction of suprahyoid muscles during swallowing, and to determine whether deficiency in muscle contraction caused a certain degree of swallowing impairment. Our results suggest that such muscle measurement has good intra- and inter-rater reliability, and has the potential to reflect actual physiological change of an important landmark (i.e., the hyoid bone). In the present study, a coronal view of the muscles was obtained. Compared to a sagittal view, this has the additional advantage of allowing muscle asymmetry to be assessed. Using ultrasonography, individual swallowing muscles can be visualized in real time, quantitatively measured, and hence clinically monitored. In addition, ultrasonography is preferred to other noninvasive techniques such as MRI in terms of image quality. A comparison of ultrasound versus MRI images of the submental muscles concluded that the muscle group was better outlined on ultrasound images.[26] These leave open the possibility of ultrasonography becoming a reliable means of biofeedback during dysphagia treatment.

Compared with VFSS, the ultrasound technique employed in this study is not capable of visualizing aspiration, which is an important variable in dysphagia assessment. However, the technique may play a better role during the preclinical stage of dysphagia by being capable of detecting changes in suprahyoid muscles.

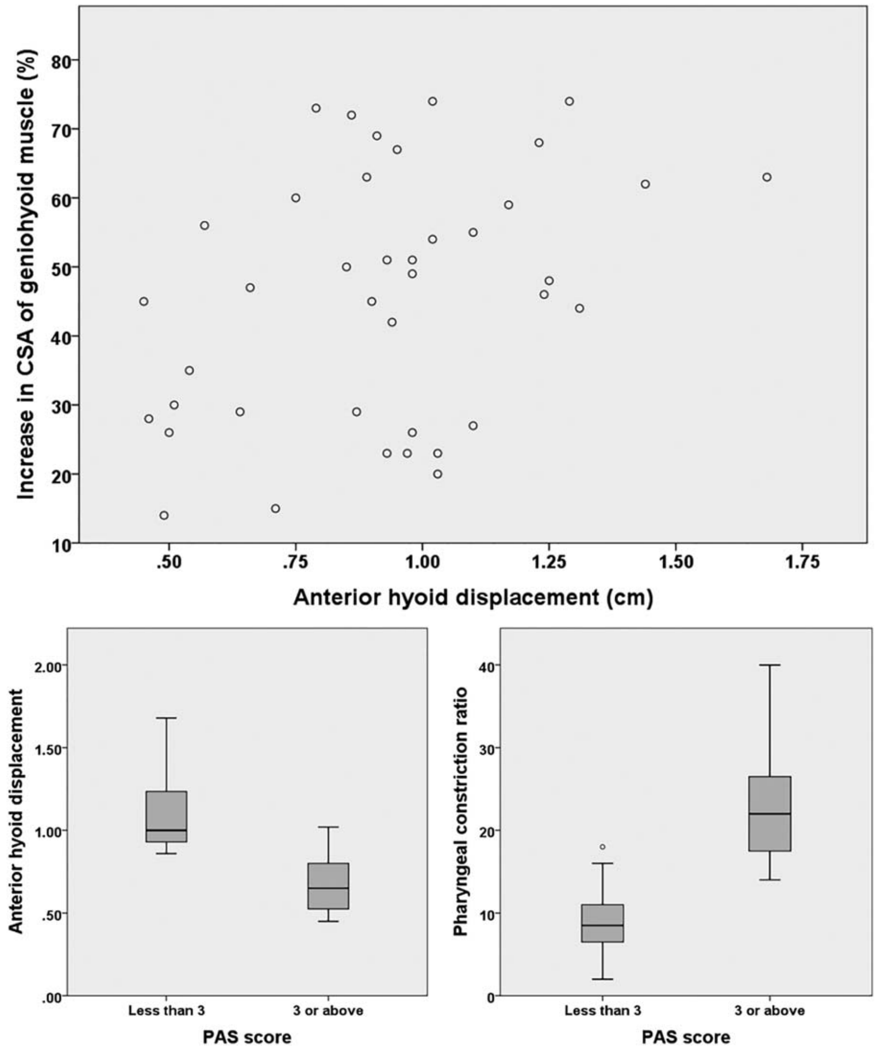

Fig. 5. (Top) A scatterplot of increase in cross-sectional area of geniohyoid muscle against anterior hyoid displacement ($r = 0.42$, $P < .05$). (Bottom Left) A boxplot of anterior hyoid displacement against PAS score. (Bottom Right) A boxplot of pharyngeal constriction ratio against PAS score.

This is particularly important for post-RT head and neck cancer patients, in which the development of swallowing problems may occur many years after treatment and is progressive in nature. Apart from detecting aspiration, the major goal of swallowing evaluation of these patients is to examine the functional integrity of important swallowing muscles, which are susceptible to radiation damage. Such a goal would be best achieved using sonographic methods. It is expected that with regular monitoring of swallowing function as well as muscle function, early identification of and intervention for deterioration can be provided so that the prevalence of clinical dysphagia and aspiration events can be reduced.

TABLE IV.
Results of Logistic Regression Model for Penetration-Aspiration

Variable	Coefficient	OR	95% CI	*P* Value
Anterior hyoid displacement	−3.962	0.019	0.001 to 0.560	.022
Pharyngeal constriction ratio	0.611	1.842	1.196 to 2.837	.015

CI = confidence interval; OR = odds ratio.

Limitations

A few issues in the present study need to be considered when interpreting the results. Firstly, patients who were tube fed were excluded from this study due to safety and ethical concerns. As a result, it may appear as though swallowing data obtained may not have reflected the true severity and pathophysiology of dysphagia experienced by post-RT NPC patients. It is worth noting, however, that a review of medical records identified a few participants who had been orally fed against medical advice at the time of recruitment (which is not uncommon given relatively young and active age of NPC survivors). Of the 40 participants in this study, three received a DOSS score of 1 or 2 (i.e., requiring nonoral nutrition). We believe that these patients were representative of those located at the severe end of the dysphagia spectrum, minimizing the effect of the selection bias concerned. Secondly, the change in CSA of the suprahyoid muscle obtained from sonographic measurement was used to represent muscle contraction. However, it was suggested that to measure the strength of individual suprahyoid muscles, the physiological CSA also needed to be obtained.[27] This parameter has to be derived from a number of physical properties, including muscle mass and density, which can only be measured from cadaver specimens. Thirdly, as the ultrasound transducer was not placed at the anatomical midpoint of the target muscle, it is not possible to conduct intersubject comparison of the muscle size. Given that our objective was to measure the degree of CSA change of a muscle during contraction, the chosen transducer placement just above the hyoid bone was found to best allow simultaneous visualization of all suprahyoid muscles concerned. Fourthly, only one of the suprahyoid muscles, the geniohyoid, was analyzed in the present study. Other muscles could have also played a role in moving the hyoid bone during swallowing. As a result, no conclusion can be made as to whether the geniohyoid muscle is the only muscle responsible for anterior hyoid displacement until other muscles have been analyzed.

Future Direction

The next step forward is to refine the sonographic technique and define more parameters so that more researchers will be able to help in standardizing the tool. Further longitudinal studies are required to provide support for the clinical utilization of ultrasonography in dysphagia management of various clinical and pathological conditions. A comparison of ultrasonography with VFSS or fiberoptic endoscopic evaluation of swallowing (FEES), in terms of sensitivity and specificity in identifying dysphagia, may underscore its importance as an alternative means of swallowing assessment. A comparison with FEES is interesting in particular, because both examinations have the same appeal in terms of convenience and patient safety, and both allow visualization of different physiological elements of swallowing.

CONCLUSION

Irradiation-treated NPC patients require long-term follow-up and monitoring of their swallowing function, which often deteriorates over time. The use of submental ultrasonography as a simple and quick screening tool to assess the function of swallowing muscles is supported by the present study. We believe that sonographic measurement of suprahyoid muscles is potentially a useful clinical tool in the diagnosis of dysphagia and subsequent intervention planning. Further research is required to refine the role of this examination in dysphagia management.

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