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ORIGINAL ARTICLE

Dosimetric Study of Acute Dysphagia in Patients with Laryngeal Carcinoma Irradiation

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ABSTRACT

Background: Dysphagia has been reported in up to 28% of head and neck carcinoma. Dysphagia results from acute tissue injury that causes mucosal damage, edema, and neuromuscular dysfunction. Neurogenic dysfunction contributes to the development of dysphagia brought on by radiation. Aspiration can occur up to 68% of the time after chemoradiation for head and neck carcinoma. We aimed to improve the treatment out come in patients with head and neck cancer.

Methods: This prospective cohort study involved 36 patients diagnosed with head and neck squamous cell carcinoma. The patients received radiotherapy ± chemotherapy. The study focused on the predictors of acute dysphagia.

Results: Higher mean doses to the superior constrictor muscle (SCM), middle constrictor muscle (MCM), and inferior constrictor muscle (ICM) were associated with higher odds of developing Grade III dysphagia: SCM mean (Gy): 1.5 times (95% CI: 1.16-1.90), MCM mean (Gy): 1.2 times (95% CI: 1.05-1.39), and ICM mean (Gy): 1.4 times (95% CI: 1.1-1.77).

Conclusions: Elevated mean doses to the SCM, MCM, ICM, and esophagus were significant predictive factors for severe dysphagia.

Keywords: Neck; Carcinoma, Irradiation; Dosimetric ; Constrictor Muscle; Dysphagia.

INTRODUCTION

Worldwide, Cancer of the head and neck remain a serious health concern., As of 2023, there were around 930,000 new cases and 467,000 recorded deaths annually. Low- and middle-income countries (LMICs), especially those in South Asia and Sub-Saharan Africa, are seeing an increase in the incidence of head and neck cancers (HNC). This increase is largely attributed to widespread tobacco consumption, the chewing of betel quid, and restricted access to healthcare facilities. HPV-16 continues to be the predominant subtype linked with oropharyngeal cancers [1].

Dysphagia, or difficulty swallowing, is a frequent and impairing complication that arises after irradiation for cancer of the head and neck, especially in those receiving chemotherapy or radiation therapy (RT or CRT). Dysphagia has been reported in up to 28% of every individual suffering from head and neck carcinoma. When dysphagia is first diagnosed, its prevalence usually increases during treatment and continues into long-term post-treatment surveillance, eventually impacting between 45% and 75% of carcinoma of the head and neck survivors [2].

Dysphagia often results from acute tissue injury that causes mucosal damage, edema,

and neuromuscular dysfunction. Chronic fibrosis, scarring, strictures, and muscle atrophy are common long-term consequences. Additionally, neurogenic dysfunction contributes to the development of dysphagia brought on by radiation [3].

Aspiration can occur up to 68% of the time after chemoradiation for head and neck carcinoma. Although aspiration pneumonia has a documented frequency of 14.54%, not all individuals who have aspiration will acquire the illness. Changes in mucosal lubrication and harm to the salivary glands can lead to xerostomia. Exposure to radiation causes the release of cytokines that promote inflammation. induces oxidative stress.**)** The dose and volume of radiation, along with concurrent chemotherapy, are contributing factors to dysphagia [4].

The radiation dose to swallowing structures, concurrent chemotherapy, and the fractionation schedule serve as predictive factors for dysphagia following chemoradiotherapy (CRT). Baseline swallowing function, tumor location, stage, age, and comorbidities are patient-related factors that predict the likelihood of dysphagia [5].

Psychosocial and behavioral factors, such as compliance with swallowing exercises both during and following radiation therapy and chemotherapy and maintaining good nutritional status, can lead to improved swallowing outcomes. A typical treatment for individuals who have severe dysphagia following radiation therapy for head and neck cancer is the insertion of an endoscopic gastrostomy tube percutaneously [6].

The study focused on enhancing treatment results for patients with carcinoma of the head and neck undergoing radiation therapy.

METHODS

The Clinical Oncology and Nuclear Medicine Department of Zagazig University Hospitals will carry out prospective cohort research involving 36 patients from September 2023 to March 2025. The research ethics committee of Zagazig University's Faculty of Medicine approved the study, and all subjects gave written informed consent. The study complied with the Declaration of Helsinki's ethical guidelines for research involving human subjects. (Approval no.: 11064-13/9/2023).

Patients with head and neck squamous cell carcinoma that has been histologically verified, patients of any grade and disease stage ranging from I to IVB, patients undergoing either postoperative or radical radiotherapy, age under 70 years, and performance status of 1 or 2 on the ECOG scale with normal hematological, renal, and liver functions were included in the study.

Patients with persistent or recurrent tumors, remote metastases, previous radiation for a palliative purpose or for another tumor of the head and neck, and diagnoses other than squamous cell carcinomas were excluded from the study.

All participants underwent a comprehensive medical history review and a thorough examination, which included a complete ENT assessment, as well as dental and nutritional evaluations. The research team measured the height, weight, and BMI of every patient. Preparatory CT and MRI scans of the head and neck were conducted to ensure detailed imaging of the affected areas.

For treatment planning, patients underwent simulation and were positioned in the most comfortable posture possible. CT scans were performed using multislice CT technology at intervals of 0.3 to 0.5 cm in the same simulated position. Tumor delineation was carried out as follows: (1) The primary gross tumor volume (GTV) and clinical target volume (CTV) encompassed the entire primary subsite; (2) nodal volumes were identified as the draining nodal region associated with the primary tumor volume.

The department's protocol adhered to established guidelines for the delineation of neck node levels for head and neck tumors **[7].** The final planning target volume (PTV) was different from the clinical target volume (CTV), which comprised both the main and nodal CTV and was set at an institutional standard of 7 mm. The organs at risk (OARs) delineated included the left and right parotid glands, spinal cord, brain stem, eyes, lens, optic chiasma, optic nerve, and mandible. These OARs were delineated in compliance with the guidelines established by the Danish Cancer Head and Neck Study Group (DAHANCA)[8]. The dysphagia/aspiration-related structures (DARS) identified for careful monitoring and management included the superior constrictor muscles (SCM), middle constrictor muscles (MCM), inferior constrictor muscles (ICM), base of tongue (BOT), larynx, and the cricopharyngeal muscle/upper esophageal sphincter (UES). Different radiation doses relative to the volumes of these structures were meticulously determined to optimize treatment effectiveness while minimizing potential complications [9]. Photon energy was administered in dosages between 60 and 70 Gy, either alone or in combination with electron energy between 4 MeV and 8 MeV. The doses for electron beam therapy varied from 10 to 20 Gy. This approach allowed for a tailored treatment plan that could effectively target the cancer while minimizing exposure to surrounding healthy tissues.

The dosimetric Planned target volume (PTV) parameters such as V95% (the amount of volume obtained 95% of the recommended dosage), V90% (90% of the recommended dosage was received by the volume), Maximum dosage, or D max, and mean dose, or D mean, were meticulously recorded. Additionally, the mean dose for individual patients and the mean doses, V50, and V60 (volumes that are received 50% and 60% of the required dosage, respectively) of the swallowing structures, as well as for the combined swallowing structures, were tabulated for the 3D conformal radiation therapy (3D-CRT).

Concurrent with the radiotherapy, chemotherapy agents such as cisplatin, carboplatin, and 5-fluorouracil (5-FU) were administered to enhance the treatment efficacy. This combination therapy approach aims to maximize cancer control while carefully monitoring and managing the radiation dose to critical structures to minimize side effects.

Post-treatment, patients were assessed weekly for acute dysphagia using the acute RTOG (Radiation Therapy Oncology Group) morbidity scoring criteria. These assessments were conducted from the start of radiotherapy and continued for 90 days post-treatment. Additionally, body mass index (BMI), changes in weight, and any interruptions in treatment were closely monitored.

Radiological examinations, including CT scans or MRIs, were scheduled two months after the conclusion of radiotherapy to evaluate treatment outcomes based on the standards set by the World Health Organization (WHO). This follow-up aimed to track the effectiveness of the treatment and identify any residual or recurrent disease, providing crucial data for ongoing patient management [10].

Statistical analysis

Data management was done using SPSS IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp. t-test, Mann-Whitney test, repeated-measures ANOVA, chi-square test, Fisher exact test. Marginal homogeneity test and multiple logistic regression were used.

RESULTS

The mean age of all patients was 60.5±8.47, ranging from 44 to 80 years old, with 80.6% aged over 50. 69.47% of patients were males. As regards residence, 63.9% were from rural areas, and 25% of them were non-smokers, 52.8% were ex-smokers, and 16.7% were current smokers. 44.4% of patients had hypertension and 22.2% had diabetes. Regarding patients' complaints, 83.3% reported hoarseness of voice, 52.8% had throat pain, 47.2% experienced neck swelling, 33.3% complained of headache, 13.9% had neck pain, 8.3% reported nasal bleeding, and 8.3% had facial pain. A small proportion of patients (5.6% each) reported weakness of mastication, nasal discharge, nasal obstruction, and nasal twang of speech. Additionally, one patient complained of ear pain and another of an ulcer. ECOG performance status was distributed as follows: 2.8% were ECOG 0, 50% were ECOG 1, and 47.2% were ECOG 2. There was no statistically significant association between dysphagia grade and the patients' personal or clinical characteristics, p > p>0.05 **(Table 1).**

T staging showed that 33.3% of patients were classified as stage T4a. In terms of nodal involvement, the majority (61.1%) were N0, followed by 22.2% with N1, 11.1% with N2, and 5.6% with Nx. As for overall clinical staging according to the AJCC system, 27.8% of patients were at stage I, while the largest group, 41.7%, were classified as stage IVA **(Table 2).**

There is a statistically significant relationship between the grade of dysphagia and the pathology staging of the tumor in the studied patients, p < p<0.05, dysphagia grade III patients had significantly late pathology and clinical staging **(Table 2).**

Site of tumor distributed as follows: 30.6% supraglottic, 58.3% glottic, and 11.1% subglottic. There was no significant difference between supraglottic tumor and subglottic tumor regarding aspiration occurrence, p > p>0.05 N.B. None of the patients with glottis tumors had aspiration. Dysphagia in patients on radiotherapy was grade I in 27.8% of patients and grade II in 19.4% of patients. 52.8% of cancer patients had dysphagia grade III. There is an association between the site of the tumor and the dysphagia grade; 52.6% of patients with supraglottic tumors had grade III dysphagia, p-value = 0.0001. There is an association between aspiration and dysphagia grade. 36.8% of patients who complained of aspiration had grade III dysphagia, p-value = 0.012 **(Table 3**).

Grade I/II dysphagia was significantly more common among patients on concurrent chemotherapy (88.2%) compared to grade III (21.1%), p = 0.0005. Grade III dysphagia was associated with higher radiation dose and volume (p < 0.05). Radiotherapy interruption and feeding tube placement occurred in 21.1% of grade III cases, versus 11.8% and 0%, respectively, in grade I/II, though these differences were not statistically significant (p > 0.05)**.**

There was a significant higher SCM V50 (%), SCM mean (Gy), MCM mean (Gy), ICM V50 (%), ICM mean (Gy), Esophagus V50 (%), Esophagus V60 (%), and V50(%),V60(%), esophagus mean (Gy) value in patients need percutaneous feeding tube compared oral feeding patients, p<0.05 Otherwise there is no statistically relation between dosimetric in Head and Neck Irradiation and percutaneous feeding tube feeding p>0.05 **(Table 4).**

Percutaneous feeding tubes were placed in 4 patients (27.8%). No statistically significant association was found between dosimetric parameters and feeding pattern.

During three months of follow from time of end radiotherapy: There was a significant p= 0.001 improvement in acute dysphagia grade comparing to their state at end of radiotherapy, p<0.05.

Univariate analysis showed that an increase in SCM V50 (%) was associated with a 1.1-fold higher odds of developing Grade III dysphagia (95% CI: 1.01–1.4). Similarly, higher SCM mean dose (Gy) increased the odds by 1.5 times (95% CI: 1.16–1.90), MCM mean dose by 1.2 times (95% CI: 1.05–1.39), ICM mean dose by 1.4 times (95% CI: 1.1–1.77), and esophagus mean dose by 1.18 times (95% CI: 1.03–1.36).Multivariate analysis confirmed that increased SCM mean dose (Gy) was a significant independent predictor of Grade III dysphagia (p = 0.036; 95% CI for Exp(B): 1.024–2.088).

At an optimal cut-off value of ≥45 Gy for SCM mean dose, the AUC was 0.858 (95% CI: 0.728–0.984), with 78.9% sensitivity, 70.6% specificity, and 75% overall accuracy for predicting Grade III dysphagia. **(Figure 1).**

Table (1): Personal and clinical characters of studied head-neck cancer patients (n.36):

Variables	n.	%
Age group		
≤50 years	7	19.4
>50 years	29	80.6
Mean ±SD range	61.5±8.47 44-80	
gender		
Males	25	69.4
Females	11	30.6
residence		
Rural	23	63.9
Urban	13	36.1
Special habit		
Non-smoker	9	25.0
Ex-smoker	19	52.8
Current smoker	8	22.2
Comorbidities	19	52.8
Hypertension	16	44.4
Diabetes mellitus	8	22.2
Heart disease	2	5.6
Complaint		
Hoarseness of voice	30	83.3
Throat pain	19	52.8
Neck Swelling	15	41.7
Headache	12	33.3
Neck pain	5	13.9
Nasal bleeding	4	11.1
Facial pain	3	8.3
Weakness of mastication	2	5.6
Nasal discharge	2	5.6
Nasal obstruction	2	5.6

Variables	n.	%
Nasal twang of speech	2	5.6
Ulcer	1	2.8
Ear pain	1	2.8
ECOG		
ECOG0	1	2.8
ECOG1	18	50.0
ECOG2	17	47.2

Table (2): Association between dysphagia grade and pathology staging of studied patients (n.36).

Variables	Dysphagia				χ^2	p-value
	Dysphagia grade I,II n.17		Dysphagia grade III n.19			
	No.	%	No.	%		
T staging						
pT1	6	35.3	0	.0		
pT2	8	47.1	3	15.8	20.37	0.0001*
pT3	3	17.6	4	21.0		
pT4a	0	.0	12	63.2		
N staging						
pN0 22	15	88.2	7	36.8		
pN1 8	2	11.8	6	31.6	10.83	0.013*
pN2 4	0	0.0	4	21.1		
pNx 2	0	0.0	2	10.5		
Clinical AJCC staging						
Stage I	10	58.8	0	.0		
Stage II	4	23.5	0	.0	29.12	0.0001*
Stage III	3	17.7	4	21.1		
Stage IV	0	.0	15	78.9		

χ 2: Chi-Square test, f: Fisher Exact test p>0.05: no significant

Table (3): Association between dysphagia grade and site of tumor of studied patients (n.36).

variables	Dysphagia				χ^2	p-value
	Dysphagia grade I,II n.17		Dysphagia grade III n.19			
	No.	%	No.	%		
Tumor site						
Supraglottic	1	5.9	10	52.6	17.1	0.0001*
Glottic	16	94.1	5	26.3		
Subglottic	0	0.0	4	21.1		
aspiration						
No	17	100.0	12	63.2		
Yes	0	0.0	7	36.8	F	0.012*

χ 2: Chi-Square test, f: Fisher Exact test p>0.05: no significant

Table (4): Relation between PTF and dosimetric data in cancer head and neck patients.

Dosimetry	Oral feeding n.32	PTF n.4	T	P
BOT mean (Gy)	33(0.00-49)	38.5(0.00-45)	0.86u	0.39
SCM Volume (cc)	6.77±1.31 4-9	6.78±1.36 5.5-8.5	.013	.989
SCM V50(%)	71±12.25 49-88	84.75±6.65 75-89	**2.186**	**.036***
SCM V60(%)	48.63±11.49 20-70	56.75±7.81 50-68	1.366	.181
SCM mean (Gy)	54.22±3.79 48-60	59.75±0.5 59-60	**2.88**	**.007***
MCM Volume (cc)	1.41±0.33 0.9-2.2	1.5±0.22 1.2-1.7	.534	.597
MCM V50(%)	75.69±13.72 55-100	83.5±4.04 80-87	1.120	.270
MCM V60(%)	17.5(9-65)	20(14-31)	0.303u	0.76
MCM mean (Gy)	47.75±5.57 39-56	54.5±1 53-55	**2.389**	**.023***
ICM Volume(cc)	1.77±0.45 1-2.6	2.05±0.34 1.7-2.5	1.228	.228
ICM V50(%)	44.63±4.11 38-50	49±1.41 47-50	**2.090**	**.044***
ICM V60(%)	20.59±4.82 12-37	22.5±1.73 20-24	0.776	0.443
ICM mean (Gy)	43.75±4.24 35-49	49.5±1 48-50	**2.67**	**.012***

Dosimetry	Oral feeding n.32	PTF n.4	T	P
Cricopharyngus m Volume(cc)	1.59±0.38 1.1-3	1.88±0.33 1.4-2.1	1.428	0.162
Cricopharyngus m V50(%)	22.5(2.3-32)	23(3.8-32)	0.328	0.74
Cricopharyngusms Mean(Gy)	40.86±6.24 30-59	45±4.97 39-51	1.272	.212
Esophagus volume(cc)	11.03±2.17 6-15	13.03±2.31 10.4-15.7	1.728	.093
Esophagus V50(%)	4.01±3.89 0.00-13	12.7±3.96 6.8-15	**4.197**	**0.0001***
	1.03±2.55 0.00-10	6.5±4.36 0.00-9	**3.744**	**0.001***
Esophagus mean (Gy)	19.72±5.87 12-32	26±3.65 22-30	**2.01**	**0.046***

Data expressed by mean, standard deviation, t student' t test, u: Mann whitnney u test, p≥0.05 no significant, p<0.05 significant

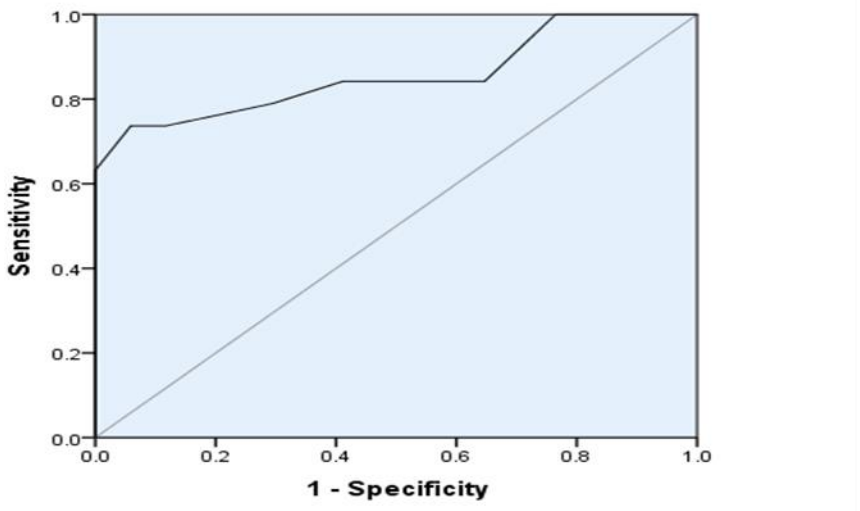

Figure (1): ROC Performance of SCM mean (Gy) in detecting Grade III dysphagia.

DISCUSSION

This study aimed to evaluate clinical and dosimetric factors influencing dysphagia in head and neck cancer patients undergoing radiotherapy. It explored the association between dysphagia severity and tumor characteristics, as well as treatment modalities—a common and serious complication of such therapies. The cohort included 36 patients, predominantly male (69.4%), with a mean age of 61.5 years, and 63.9% from rural areas. These findings offer valuable insights into the challenges of managing and mitigating dysphagia in this patient group.

All tumors in our study were laryngeal, with the glottic region being the most prevalent subsite, accounting for 58.3% of cases. This finding contrasts with other studies where oropharyngeal cancers are more dominant, often due to HPV-associated trends[11]. However, our subsite distribution is consistent with findings from another study [12], where glottic tumors comprised a significant portion of laryngeal cancers. This underscores the variability in tumor subsite prevalence across different populations and geographic regions in that U.S. cohort, glottic tumors accounted for 60% of all laryngeal cancers [12].

According to Almeida et al.16 [13], significantly greater weight loss was associated with several factors: omission of prophylactic PEG tube insertion ($p < 0.00001$), younger age ($p = 0.0032$), and the use of adjuvant concurrent chemoradiotherapy (CCRT) ($p = 0.0005$). Additionally, the risk of prolonged feeding tube dependence (more than six months) was significantly higher in patients who had received a prophylactic PEG tube ($p < 0.0001$) and in those older than the median age of 60.8 years ($p = 0.0165$) as per multivariate analysis. Interestingly, the insertion of a prophylactic PEG tube was not found to significantly improve global health status, overall survival, or progression-free survival in univariate analysis. On the other hand, none of the patients in our research chose to have a prophylactic PEG tube because they refused to have one.

In our study, 11.1% of patients required percutaneous feeding tubes (PFTs), and notably, all these cases were among those who developed grade III dysphagia. This finding is in line with the results reported by Lee et al. [14], who found that 10–15% of head and neck cancer patients undergoing radiotherapy required PFTs, particularly those who have severe dysphagia or advanced-stage illness. These observations highlight the strong association between dysphagia severity and the need for nutritional support during and after radiotherapy.

Zhang et al. [15] found that aspiration was a strong predictor for the insertion of percutaneous feeding tubes (PFTs), with 30% of patients who experienced aspiration requiring PFT placement This observation aligns with our research findings., as all patients in our study who required PFTs had grade III dysphagia, a condition often associated with a high risk of aspiration. This further reinforces the link between severe swallowing dysfunction, aspiration, and the subsequent need for enteral nutritional support.

In our study, patients who required percutaneous feeding tubes (PFTs) received significantly higher mean radiation doses to critical swallowing-related structures, including the superior constrictor muscle (SCM) at 59.75 ± 0.5 Gy, the middle constrictor muscle (MCM) at 54.5 ± 1 Gy, and the esophagus at 26 ± 3.65 Gy, when compared to those who did not require PFTs. These findings are in agreement with [16], who found a substantial correlation between a higher chance of PFT insertion and higher radiation doses to important swallowing structures. This underscores the

importance of dosimetric planning to minimize radiation exposure to these vulnerable anatomical regions.

in our study, higher radiation doses to key swallowing-related structures—such as the superior constrictor muscle (SCM), middle constrictor muscle (MCM), inferior constrictor muscle (ICM), and the esophagus—were strongly associated with the development of grade III dysphagia. Among these, the mean dose to the SCM emerged as a particularly significant predictor of severe dysphagia, with an odds ratio of 1.463 and a 95% confidence interval of 1.024–2.088. These findings emphasize the importance of carefully planning radiation therapy and optimizing the doses to these critical structures in order to reduce the likelihood of severe swallowing difficulties in patients with head and neck cancer [18].

In one study, For the dysphagia/aspiration-related structures (DARS), a dosage constraint of 50 Gy was used; however, adherence to this constraint was not mandatory [17]. This approach was guided by findings from [18], who also selected a 50 Gy threshold based on observations that this dose was near the minimum level associated with the development of strictures in most pharyngeal constrictor muscles. Similarly, [19] implemented a 50 Gy mean dose constraint for DARS-sparing intensity-modulated radiotherapy (IMRT) in laryngeal cancer. Nonetheless, achieving this constraint was not compulsory in their protocol, especially when tumor proximity to the pharynx necessitated higher doses.

A study by Feng et al. [20] specifically evaluated IMRT for reducing dysphagia and found that maintaining DARS doses below 45 Gy effectively prevented aspiration events. Furthermore, **van** der Molen et al. [21**]** showed that mean doses exceeding 63 Gy to the superior and middle constrictor muscles (SCM and MCM) were associated with a notable decline in swallowing quality. Consistent with this, Forastiere et al. [22] found that when pharyngeal constrictors were exposed to similar high-dose conditions, there was a collective reduction in swallowing function. These findings support the implementation of dose constraints to protect DARS and mitigate dysphagia-related complications while treating head and neck cancer.

Manam et al. [17**]** revealed that patients receiving three-dimensional conformal radiation therapy (3D-CRT) received an average radiation dosage of 57.55 Gy to the superior constrictor muscle (SCM) and 62.40 Gy to the middle constrictor muscle (MCM). In contrast, intensity-modulated radiotherapy (IMRT) significantly reduced these doses to 51.06 Gy for the SCM and 59.37 Gy for the MCM.

Similarly**,** Upadhyay et al. [23**]** found A significant advantage was seen with intensity-modulated radiotherapy technique (IMRT) in comparison to three-dimensional conformal radiotherapy (3D-CRT) in terms of mean dose delivered to the pharyngeal constrictor muscles (66.03 Gy vs 68.77 Gy, p=0.003). The mean dose delivered to the combined dysphagia/aspiration-related structures (DARS) was statistically significantly lower in IMRT compared to 3D-CRT (66.15 Gy vs. 70.09 Gy, p<0.001). Other dose-volumes were also reduced in IMRT group (V30: {98.64% vs. 99.88%, p=0.05}; V50: {90.49% vs. 99.02%, p=0.0002}; V60: {83.92% vs. 95.04, p=0.0002}; D50: {70 Gy vs. 71.16 Gy, p=0.001); and D80: {61.18 Gy vs. 67.39 Gy, p=0.01}.

Furthermore, the incidence of clinical worsening of dysphagia was significantly lower in the IMRT group compared to the 3D-CRT group (48% vs. 80%, p=0.039). In univariate analysis, higher mean doses to the SCM and MCM, portions of these muscles that received at least 50 Gy, and total doses

≥60 Gy to the entire constrictor complex, along with tumor location, were all associated with late dysphagia. However, multivariable analysis identified the mean dose to the MCM as the only statistically significant predictor of late dysphagia [24].

These findings strongly support the use of IMRT over 3D-CRT in head and neck cancer treatment to reduce radiation-induced dysphagia by sparing critical swallowing structures.

Duprez et al. [25] reported that the mean dose to the pharyngeal constrictor muscles is one of the most critical dosimetric predictors of late-onset swallowing dysfunction. They emphasized the need for further validation of proposed dose-volume relationships through well-designed prospective clinical trials that utilize appropriate statistical methods to control for potential confounding variables.

In alignment with these findings, our multivariate logistic regression analysis identified the mean dose to the superior constrictor muscle (SCM) as an independent predictor of grade III dysphagia, with an odds ratio of 1.463 (95% CI: 1.024–2.088). This underscores the importance of precise radiation planning and minimizing exposure to critical swallowing structures to reduce the risk of severe dysphagia in head and neck cancer patients [17].

Regarding dose constraints, it is recommended to limit radiation to swallowing-related muscles to reduce toxicity. Specifically, mean doses should remain below 55 Gy for the SCM, 50 Gy for the middle constrictor muscle (MCM), and 20 Gy for the esophagus. These guidelines are supported by recent studies [23], which emphasize the importance of protecting these structures during radiotherapy.

To achieve these constraints without compromising tumor control, utilizing cutting-edge radiation methods is crucial. Techniques such as intensity-modulated radiotherapy (IMRT) and proton therapy have been shown to significantly reduce radiation exposure to critical swallowing-related structures. Studies by [17, 19, 23] have demonstrated that these advanced modalities not only improve dose distribution but are also associated with a marked reduction in the incidence and severity of dysphagia, underscoring their value in modern head and neck cancer treatment planning.

The study's strengths are its prospective methodology and committed follow-up, despite a number of shortcomings, such as a small sample size, its single-institution design, the lack of prophylactic PEG tube installation, and possible data bias. These elements add value by ensuring consistency in data collection and outcome monitoring.

Importantly, the study underscores the critical role of early nutritional intervention and a multidisciplinary care approach in managing dysphagia and enhancing patient outcomes. Patients who developed grade III dysphagia experienced notable weight loss during and after treatment, highlighting the urgent need for timely nutritional support. With the ultimate goal of preserving quality of life and promoting general recovery, this involves taking into account percutaneous feeding tubes in high-risk patients to avoid malnutrition and treatment disruptions.

Conclusion:

To reduce the risk of severe dysphagia, it is important to apply strict dose limits to swallowing-related structures—keeping the mean dose below 55 Gy for the SCM, 50 Gy for the MCM, and 20 Gy for the esophagus. Utilizing advanced radiation techniques like IMRT and proton therapy can help minimize exposure to these critical areas while preserving effective tumor control. Additionally, prophylactic feeding tubes should be considered for high-risk patients, including those with supraglottic tumors, advanced-stage disease, or those receiving

concurrent chemoradiotherapy, to help prevent weight loss and malnutrition.

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