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ORIGINAL ARTICLE

Pattern of dysphagia after swallowing-sparing intensity-modulated radiotherapy (IMRT) of head and neck cancers: results of a mono-institutional prospective study

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Abstract

Background and purpose A prospective instrumental assessment of late dysphagia using swallowing organs at risk (SWOARs)-sparing IMRT for nasopharyngeal and oropharyngeal cancers.

Materials and methods Objective instrumental assessment included fiberoptic endoscopic evaluation of swallowing (FEES) and videofluoroscopy (VFS) at baseline, and at 6 and 12 months after treatment. FEES assessed the pharyngeal residue according to the Farneti pooling score (P-score) as follows: 4–5 no dysphagia; 6–7 mild dysphagia; 8–9 moderate dysphagia; 10–11 severe dysphagia. Three different consistencies were tested for the P-score: liquid (L), semisolid (SS), and solid (S). VFS assessed penetration-aspiration according to the Penetration-Aspiration Scale (PAS) and two different consistencies of the bolus were tested: thin liquid barium (L) and paste barium (S).

Results 38 patients were evaluable. There was a significant worsening of the P-score at 6 months both for SS ($p=0.015$) and S ($p<0.001$), which persisted only for S at 12 months ($p<0.0001$). Similarly, there was a significant worsening of the PAS score at 6 and 12 months ($p=0.065$ and 0.039, respectively) for the S bolus. Overall, 3–7 and 10–14% aspiration after L and S was observed, respectively.

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Conclusions Promising results using a SWOARs-sparing IMRT technique are reported. Therefore, treatment plans should be optimized for reducing doses to these structures.

Keywords Radiotherapy · Dysphagia · Aspiration-pneumonia · Fiberoptic endoscopic evaluation of swallowing · Videofluoroscopy

Muster von Dysphagie nach intensitätsmodulierter Strahlentherapie unter Schonung schluckrelevanter Strukturen bei Kopf-Hals-Tumoren: Ergebnisse einer monoinstitutionellen prospektiven Studie

Zusammenfassung

Hintergrund und Zielsetzung Eine prospektive instrumentelle Einschätzung der späten Dysphagie bei intensitätsmodulierter Strahlentherapie (IMRT) unter Schonung schluckrelevanter Strukturen (SWOAR, „swallowing organs at risk“) bei Nasopharynx- und Oropharynxkarzinomen.

Material und Methoden Die objektive instrumentelle Einschätzung beinhaltete die glasfaseroptisch-endoskopische-Einschätzung des Schluckakts (FEES, „fiberoptic endoscopic evaluation of swallowing“) sowie eine Videofluoroskopie (VFS) zu Beginn sowie nach 6 und 12 Monaten nach der Behandlung. FEES bewertete den pharyngealen Restrückstand nach dem Farneti-Pooling-Score (P-Score) wie folgt: 4–5 keine Dysphagie; 6–7 leichte Dysphagie; 8–9 moderate Dysphagie; 10–11 schwere Dysphagie. Drei verschiedene Konsistenzen wurden für den P-Score getestet: flüssig (L), halbflüssig (SS) und fest (S). Die VFS bewertete Penetration und Aspiration anhand der Penetration-Aspiration-Skala (PAS). Es wurden 2 verschiedene Boluskonsistenzen geprüft: dünnflüssiger Bariumbrei (L) und dickflüssiger Bariumbrei (S).

Ergebnisse Es konnten 38 Patienten evaluiert werden. Eine signifikante Verschlechterung des P-Scores zeigte sich nach 6 Monaten sowohl für SS ($p = 0{,}015$) als auch für S ($p < 0{,}001$), der allerdings nur bei S auch nach 12 Monaten weiter bestand ($p < 0{,}0001$). Gleichermaßen ergab sich für den S-Bolus eine signifikante Verschlechterung des PAS-Werts nach 6 und 12 Monaten (jeweils $p = 0{,}065$ bzw. $p = 0{,}039$). Insgesamt wurde nach L und S eine Aspiration von jeweils 3–7 % und 10–14 % beobachtet.

Schlussfolgerung Die Ergebnisse bei Verwendung einer SWOAR-schonenden IMRT-Technik sind vielversprechend. Daher sollten die Behandlungspläne optimiert werden, um die Dosis für diese Strukturen zu verringern.

Schlüsselwörter Strahlentherapie · Dysphagie · Aspirationspneumonie · Fiberoptische endoskopische Beurteilung des Schluckens · Videofluoroskopie

Introduction

In Europe, head and neck cancer (HNC) accounted for 250,000 cases (estimated 4% percent of the cancer incidence) and 63,500 deaths in 2012 [1].

Concurrent chemoradiotherapy is the non-surgical standard of care for patients who present with high-stage disease, despite being hampered by a non-negligible rate of treatment-related dysphagia (17–24%; [2–7]). In this regard, several studies have shown that intensity-modulated RT (IMRT) might reduce the probability of post-radiation dysphagia by producing concave dose distributions with better avoidance of several critical structures such as swallowing organs at risk (SWOARs), which might result in better functional outcomes [8–11].

On the other hand, clinical evaluation of dysphagia has been proved to underestimate swallowing impairment as compared to instrumental procedures [12–14]. As complementary procedures, videofluoroscopy (VFS) and fiberoptic endoscopic evaluation of swallowing (FEES) are considered the gold standard and are both recommended to properly evaluate swallowing function in clinical practice by most experts [15].

Unfortunately, the current literature is not homogeneous in terms of radiation-related swallowing outcomes due to several methodological issues as well as regarding the different radiation techniques used. In this regard, a recent systematic review on this issue [16] seems to suggest better results with IMRT compared to 3DCRT, and strongly encourages well-designed prospective trials providing a good RT quality control for dose reduction to SWOARs together with an accurate dysphagia assessment protocol.

Therefore, we performed a prospective longitudinal study to assess the impact of RT on swallowing function. The primary aim of this study was to evaluate the changes in the objective instrumental dysphagia parameters from before to after treatment (at 6 and 12 months) using an

IMRT technique aimed to reduce the radiation dose to the swallowing-related structures (SWOARs-sparing IMRT).

Materials and methods

Study protocol

Details of patients' characteristics, radiation treatment, medical therapy, and the technical aspects of the instrumental evaluation of swallowing function have been previously reported [17]. Also, details regarding the radiotherapy planning criteria are reported in the electronic supplementary material.

In brief, eligibility criteria included all patients affected by nasopharyngeal and oropharyngeal cancers (stage II-IVA) who were candidates for a non-surgical RT-based treatment with curative intent and required bilateral neck irradiation. Indeed, different primary sites from the above-mentioned, stage IVB or C, previous induction CT and/or HNC oncologic treatment (surgery or RT), as well as diagnosis of concomitant comorbidity which might compromise deglutition function (demyelinating or degenerative diseases and connective tissue diseases) were exclusion criteria. Patients who underwent salvage surgery at the primary tumor site and those who experienced recurrence or metastatic disease within the timeframe of the study were dropped out of the study. Contrastingly, patients who underwent salvage surgery on lymph nodes after treatment were not excluded.

Objective instrumental assessment of swallowing function was made by fiberoptic endoscopic evaluation of swallowing (FEES) and videofluoroscopy (VFS) that were performed at baseline, and at 6 months and 12 months post-therapy. Both examinations were carried out by a deglutologist, a dedicated radiologist, and a speech-language pathologist, and testing was discontinued if the clinicians judged the swallowing as potentially harmful to the patients. Besides, patients were introduced to swallowing exercises aimed to strengthen supraglottic and suprahyoid musculature, airway protection, and base of tongue retraction (Mendelson and Masako maneuvers, supraglotttic and supersupraglottic swallow, and tongue resistance exercises) at any time if necessary.

FEES was specifically used to assess the severity of pharyngeal residue according to the Farneti pooling score (P-score; [18, 19]), a reliable and validated tool that significantly predicts aspirations. This score is based on the endoscopic evaluation of the site (vallecular/marginal zone/pyriform sinus vestibule/vocal cords/lower vocal cords), the amount (coating/minimum/maximum), and the management of retention as the number of dry swallows required to clear pooling (<2; 2–5; >5). It comprises 4 levels considering the minimum level as a normal condition. A P-score of 4–5 (minimum score) indicates no dysphagia; a score of 6–7 (low score) mild dysphagia; a score of 8–9 (middle score) moderate dysphagia; 10–11 (high score) severe dysphagia. Patients were asked to swallow three different

Table 1 Patients and tumor characteristics

Characteristic	*N*	%
Age (years)		
Mean	61	–
Range	42–78	–
Gender		
Male	31	79
Female	8	21
Smoking status		
No	18	46
<10 cigarettes/day	2	5
10–20 cigarettes/day	9	23
>20 cigarettes/day	10	26
Alcohol intake		
No	25	64
<1 L/day	7	18
>1 L/day	7	18
HPV status[a]		
Negative	18	62
Positive	4	14
Unknown	7	24
Primary site		
Nasopharynx	10	26
Tonsil	10	26
Soft palate	4	10
Base of tongue	15	38
T stage		
1	4	10
2	18	46
3	6	16
4	11	28
N stage		
0	14	36
1	9	23
2	16	41
AJCC stage		
II	14	36
III	6	15
IV	19	49
Medical therapy		
None	8	20
CDDP	28	72
Cetuximab	3	8

AJCC American Joint Committee on Cancer, *HPV* human papillomavirus

[a]Assessed using in situ hybridization (HPV DNA) only for patients with oropharyngeal cancer

consistencies of bolus to test the P-score: 10 mL of water marked with blue methylene (L = liquid), 10 mL of marmalade (SS = semisolid), and a piece of cracker (S = solid).

VFS was specifically used to assess the pattern of penetration and aspiration based on the Penetration-Aspiration Scale (PAS; [20, 21]). The PAS is a tool with acceptable reliability consisting of an 8-point scale ranging from 1 to 8, which was simplified by dividing it into three categories (1: normal; 2–5: penetration; 6–8: aspiration), which roughly correspond to normal, mild-to-moderate, and severe performance. Patients were asked to swallow two different consistencies of bolus twice to test the PAS score: 5–10 mL of thin liquid barium (L = liquid) and 5 mL of paste barium (S = solid).

In order to interpret and compare results, three different score values corresponding to the three different bolus consistencies (L, SS, and S) resulted for pharyngeal residual assessment (P-score) and two different score values corresponding to the two different bolus consistencies (L and S) resulted for penetration-aspiration assessment (PAS score).

Statistical analysis

Before testing the inferential statistics, a graphical exploration (bar graph) was performed.

To detect significant changes of the P-score (quantitative data) for the three different consistencies of the bolus (L, SS, and S) measured at baseline and at 6 and 12 months after treatment, the Friedman test and Wilcoxon test (two-tailed) were applied for multiple comparisons.

Variations of PAS score (qualitative data) for the two different consistencies of the bolus (L and S) measured at baseline and at 6 and 12 months after treatment were assessed by the McNemar test.

Finally, to evaluate the association between P-score (4–5 and 6–7 vs. 8–9 and 10–11) and PAS score (normal vs. penetration/aspirations), both dichotomous, the chi squared test or Fisher exact test was used as appropriate.

All statistical analyses, descriptive and inferential, were performed using SPSS v. 23 technology (IBM Corporation, Armonk, NY).

Results

Between June 2012 and October 2015, 39 patients with nasopharyngeal ($n = 10$) and oropharyngeal ($n = 29$) cancer were enrolled in our study. 38 were eligible for the evaluation of the study, as 1 patient affected by a primary base of tongue cancer died due to cardiovascular disease at 4 months after treatment. Of the 38 eligible patients, 36 patients underwent both FEES and VFS at 6 months and 30 patients underwent both FEES and VFS at 12 months.

The summaries of baseline patient and tumor characteristics and treatment details are reported in Table 1.

Median and range doses received by the SWOARs are reported in Table 2.

Of the 28 patients who underwent concomitant CT, all but 3 who interrupted CT early (1 due to high-grade nausea and vomiting and 2 due to myelotoxicity) received at least five of the planned six cycles. Only 2 patients required hospitalization and enteral nutrition (through nasogastric tube placement) during and soon after treatment, and only 1 patient developed clinical aspiration pneumonia; indeed, no patients required pre-treatment gastrostomy positioning. 1 patient was lost to follow-up at 14 months after treatment.

Among the 38 evaluable patients, 7 (18%) experienced a locoregional recurrence (6 local and 1 both local and regional), of whom 5 underwent a subsequent metastatic progression (4 lung and 1 bone metastasis). Differently, 2 patients (1 nasopharynx and 1 base of tongue) experienced distant metastases progression without locoregional evidence of recurrence.

Of the 7 patients who experienced locoregional recurrence, there were no failures within or near the swallowing-spared region. Overall, after a median follow-up of

Table 2 Median and range doses received by the SWOARs according to tumor subsite

	Nasopharynx	Base of tongue	Soft palate	Tonsil
SPCM	59.8 Gy (39.1–67.2 Gy)	55.9 Gy (13.1–62.3 Gy)	59.2 Gy (48.7–66.2 Gy)	60.8 Gy (53.2–63.5 Gy)
MPCM	44.8 Gy (30–63.4 Gy)	58.2 Gy (33.4–67 Gy)	44.1 Gy (28.4–60.6 Gy)	55.8 Gy (48.4–62.2 Gy)
IPCM	40.7 Gy (20.1–64.4 Gy)	56.6 Gy (20.3–66.9 Gy)	39.5 Gy (20–47.8 Gy)	43.1 Gy (29.3–54.6 Gy)
BOT	47.6 Gy (30.2–60.6 Gy)	57 Gy (27.9–66 Gy)	52.7 Gy (30–61.3 Gy)	59.5 Gy (50–64.4 Gy)
SL	40.9 Gy (20.1–60.4 Gy)	61 Gy (23–68.3 Gy)	43 Gy (20–58.6 Gy)	38.9 Gy (22.4–47 Gy)
GL	35.9 Gy (20.1–60.4 Gy)	50.6 Gy (17.5–67.3 Gy)	33.3 Gy (20–49.6 Gy)	38.9 Gy (22.4–47 Gy)
CPM	39.3 Gy (20.1–58.7 Gy)	41.5 Gy (16.6–60.9 Gy)	36 Gy (0–37.6 Gy)	42.6 Gy (29.3–54.5 Gy)
EC	33.3 Gy (15–47 Gy)	27.2 Gy (8–50 Gy)	16.7 Gy (0–37 Gy)	24.3 Gy (20–27 Gy)

SWOARs swallowing organs at risk; *SPCM* superior pharyngeal constrictor muscle; *MPCM* medium pharyngeal constrictor muscle; *IPCM* inferior pharyngeal constrictor muscle; *BOT* base of tongue; *SL* supra-glottic larynx; *GL* glottic larynx; *CPM* cricopharyngeal constrictor muscle; *EC* cervical esophagus

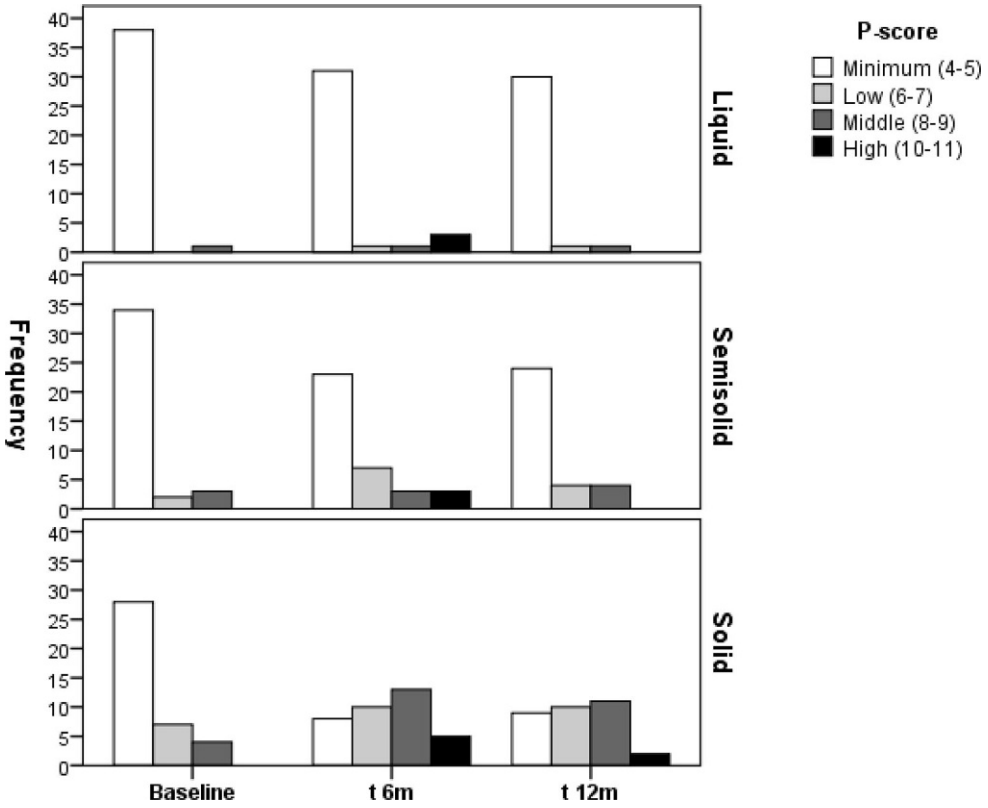

Fig. 1 The distribution of the Farneti pooling score (*P-score*) at the three different time intervals (*t*) for the three different consistencies of the bolus

33 months (range 12–56), 3 patients (7.7%) died due to cancer and 1 patient died of cardiovascular disease.

Variation of pharyngeal residue scores at FEES from baseline to after treatment

The examination of the differences between the pre- and post-treatment P-score values is reported in Table 3. As shown, no significant statistical difference was observed for L bolus ($p=0.819$), whereas an overall significant difference was observed for SS and S bolus ($p=0.043$ and $p<0.001$, respectively). Specifically, a significant worsening was shown between baseline and 6 months after treatment for both SS and S consistencies ($p=0.015$ and $p<0.001$, respectively), which was observed to persist for S ($p<0.0001$) at 12 months compared to the baseline but not for SS consistencies ($p=0.207$).

The distribution of the P-score for the three different consistencies (L, SS, and S) and at the three different time intervals is illustrated in Fig. 1. As shown, only 4 patients (11%) experienced middle or high P-score after L bolus administration at 6 months and only 1 patient experienced (3%) middle P-score at 12 months. Contrastingly, 3 patients (8%) experienced middle and 3 other patients (8%) high P-score for SS bolus at 6 months, whereas 4 patients (12.5%) experienced middle and none high P-score at 12 months. Indeed, middle and high P-score after S bolus administration was observed in 12 (33%) and in 5 (14%) patients, respectively,

Table 3 Statistical significance of Farneti pooling score (P-score) value variations for the three different consistencies for all patients and according to tumor site

	p-value RM	*p*-value MC		
Farneti FEES		t_0 vs. t_{6m}	t_0 vs. t_{12m}	t_{6m} vs. t_{12m}
Liquid	0.819	–	–	–
Semisolid	0.043	0.015	0.207	0.710
Solid	<0.0001	<0.0001	<0.0001	0.567
Semisolid nasopharynx	0.368	–	–	–
Semisolid oropharynx	0.530	–	–	–
Solid nasopharynx	0.030	0.031	0.125	0.999
Solid oropharynx	0.045	0.008	0.070	0.999

RM repeated measures; *MC* multiple comparison; *FEES* fiberoptic endoscopic evaluation of swallowing, *t* time

Table 4 Statistical significance of PAS score value variations for the three different consistencies for all patients and according to tumor site

PAS	*p*-value t_0 vs. t_{6m}	t_0 vs. t_{12m}	t_{6m} vs. t_{12m}
Liquid	0.453	0.375	0.370
Solid	0.065	0.039	0.250
Solid nasopharynx	*	*	0.999
Solid oropharynx	0.180	0.125	0.250

PAS Penetration Aspiration Scale, *t* time, * comparison was not possible

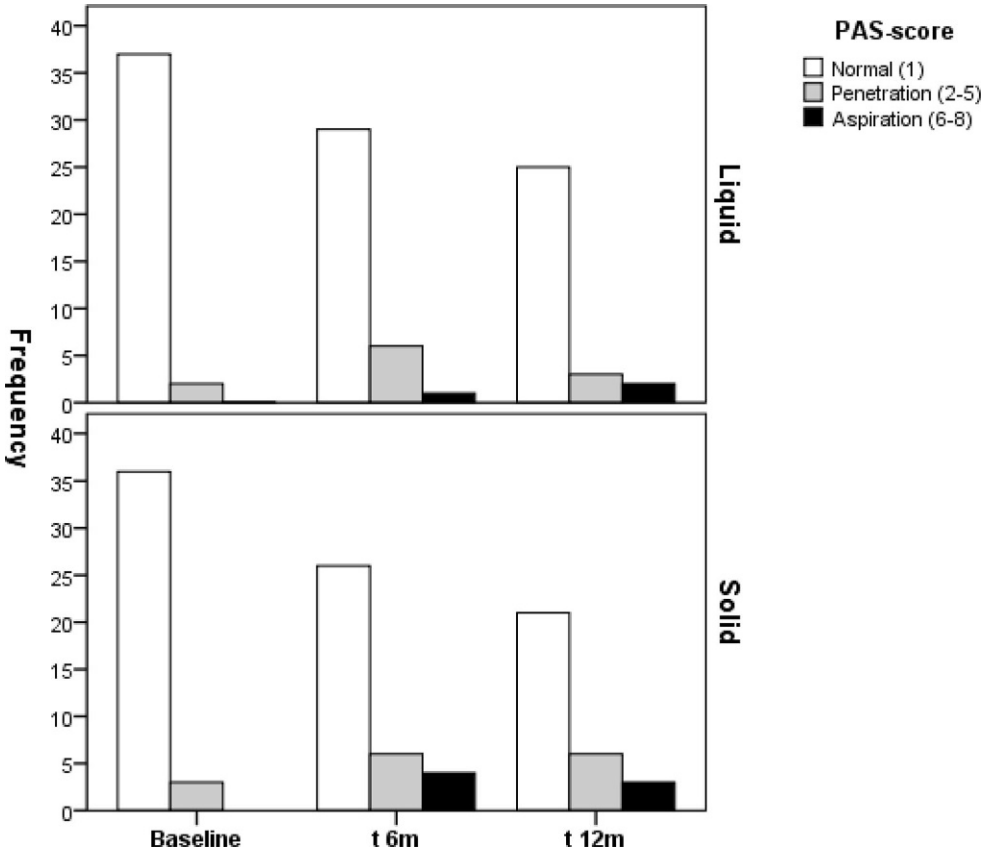

Fig. 2 The distribution of the Penetration Aspiration Scale (*PAS*) score at the three different time intervals (*t*) for the two different consistencies of the bolus

at 6 months and in 10 (31%) and 2 (6%) patients, respectively, at 12 months.

Pattern of penetration and aspiration at VFS from baseline to after treatment

The evaluation of the differences between the pre- and post-treatment penetration-aspiration rate are reported in Table 4. As shown, no statistically significant variations were observed for L bolus at any time after treatment, whereas a significant difference resulted from baseline to 12 months ($p = 0.039$) for S bolus.

The distributions of penetration-aspiration rate for the two different consistencies (L and S) are illustrated in Fig. 2. At baseline, penetration was observed in 2 patients (1 soft palate and 1 base of tongue) both after L and S bolus, and in 1 patient (soft palate) exclusively after S bolus administration; no case of aspiration was found. Indeed, penetration and aspiration were observed in 6 patients (17%) and in 1 patient (3%) after L bolus at 6 months, respectively, and in 3 patients (10%) and 2 patients (7%) after L bolus at 12 months, respectively. Finally, penetration was found in 6 patients (17%) and aspiration in 5 patients (14%) after S bolus at 6 months, and in 6 patients (20%) and 3 patients (10%), respectively, after S bolus at 12 months. Patients who aspirated after L bolus (1 patient at 6 months and 2 patients at 12 months) also aspirated after S bolus.

All the penetrations after both L and S at baseline were classified as PAS 3 (material enters the airway, remains above the vocal folds, and is not ejected) and those after treatment were classified as PAS 5 (material enters the airway, contacts the vocal folds, and is not ejected), whereas all the aspirations after both L and S after treatment were

Table 5 Association between P-score and PAS score after treatment

		p-value[a]	
		P-score L vs. PAS L	P-score S vs. PAS S
t_{6m}	t_{6m}	*<0.0001*	*0.007*
t_{12m}	t_{12m}	–	*0.026*

P-score pooling score; *PAS* Penetration-Aspiration Scale; *L* liquid; *S* solid
[a]Middle/high P-score vs. penetration/aspiration

classified as PAS 8 (material enters the airway, passes below the vocal folds, and no effort is made to eject).

Association between pharyngeal residue and penetration/aspiration after treatment

Associations between P-score and PAS score for L and S bolus are reported in Table 5. As shown, the occurrence of penetration or aspiration at VFS was strongly associated almost at any time with the presence of a middle or high P-score ($p<0.05$).

First of all, at 6 months, the 1 patient (14%) who experienced aspiration after L bolus also showed high P-score after L bolus; indeed, among the 6 patients (86%) who experienced penetration after L bolus, 3 showed high (50%), 1 middle (17%), and 2 minimum (33%) P-score. Among the 5 patients who experienced aspiration after S bolus at 6 months, 4 showed high (80%) and 1 middle (20%) P-score after S bolus. Indeed, of the other 5 patients who experienced penetration after S bolus at 6 months, 2 showed middle (40%), 1 low (20%), and 2 minimum (40%) P-score after S bolus. On the other hand, at 12 months, both the 2 patients with aspiration and the 3 patients with penetration after L showed a minimum P-score after L bolus. Finally, among the 3 patients with aspiration after S bolus at 12 months, 2 showed high (67%) and 1 middle (33%) P-score after S; indeed, of the 6 patients who experienced penetration after S at 12 months, 3 showed high (50%), 2 middle (33%), and 1 low (17%) P-score after S.

Discussion

Our study was specifically focused to investigate the impact of an "intent SWOARs-sparing IMRT" on swallowing function in a subset of HNCs almost homogeneous for oncologic therapy and RT treatment volumes. To this aim, a complementary assessment protocol (both FEES and VFS) was used to properly grade both the severity of pharyngeal residue (Farneti P-score) and the presence of penetration or aspiration combined with the preservation of coughing protective reflexes (PAS score), as recommended by most experts [15, 22, 23].

First of all, the results of our study showed a significant impairment of deglutition for more solid consistencies both in terms of P-score ($p=0.043$ and $p<0.0001$ for SS and S, respectively) and PAS score ($p=0.039$ for S), which was not observed for L consistencies ($p>0.1$). Upon more detailed analysis, a significant worsening occurred both for SS and S consistencies at 6 months, whereas a significant persistence of the swallowing impairment seemed to occur only for S ($p<0.0001$) at 12 months after treatment. In this regard, based on the P-score, an overall 16% of patients were affected by moderate or severe dysphagia at 6 months, whereas 12.5% of patients were only affected by moderate (and no one by severe) dysphagia after SS bolus at 12 months after treatment. On the contrary, moderate or severe dysphagia was observed after S bolus in 47 and 37% of patients at 6 and 12 months after treatment. Similarly, according to the PAS score, we found an overall penetration/aspiration rate of 20 and 17% after L bolus at 6 and 12 months, respectively, and of 30% after S bolus both at 6 and 12 months.

As far as we know, this is the only study reporting data on radiation-related swallowing impairment using a standardized instrumental assessment protocol based on the combination of both VFS and FEES, and itemized for the different consistencies of the bolus. Our results, which clearly underline the greater swallowing impairment for mores solid consistencies, seem to be confirmed by Pauloski et al. [24], who, albeit in a very small number of patients, found out a significant greater reduction of oropharyngeal swallowing efficiency (OPSE) for S rather than L bolus. According to the current literature, the penetration-aspiration rate was the most-used tool to report the severity of post-treatment dysphagia [25–31], whereas the pattern of pharyngeal residue, reported by fewer authors [17, 32–34], was usually limited by the lack of a standardized score to quantify the amount of bolus retained in the pharynx, which made it difficult to compare the results of the different studies. However, our clinical results seem to be consistent with those provided by the recent literature on this topic, reporting an overall pattern of aspiration and penetration of 2.6–26 and 11–31%, respectively, after IMRT [35]. In this regard, Feng et al. [36], in a larger mono-institutional trial on 73 oropharyngeal cancers which had undergone RTCT, reported an overall 26–20% of VFS-based aspirations at 1 and 2 years. Moreover, Schwartz et al. [37], in a prospective trial on 31 oropharyngeal cancers, reported an overall 4–6% of aspirations between 6 and 24 months after treatment. More

recently, the study by Van Der Molen et al. [38] on a more heterogeneous HNC population found 11% penetration and 3% aspiration at 12 months after treatment, whereas Kumar et al. [34] reported a 35% penetration-aspiration rate between 6 and 24 months after treatment. Likewise, our results seem to agree with the study by Patterson et al. [33], who examined the pharyngeal residue using FEES after IMRT on 18 nasopharyngeal cancers, reporting a 44% pattern of severe retention.

Secondly, we almost always observed an important association between the occurrence of penetration or aspiration and the presence of severe or moderate dysphagia (high or middle P-score), which, in our opinion, statistically confirmed the correlation between the aspiration and the grade of radiation-induced post-swallowing residue which has been reported in the literature [17, 18, 23]. Upon a more detailed analysis of our data, this correlation came out mostly with the occurrence of aspiration rather than penetration and after the administration of S rather than L consistencies. In fact, 100% of the patients who experienced aspiration after S at both 6 and 12 months had middle or high P-score, whereas among those who experienced penetration after S, only 40% of had moderate P-score and 60% had minimum or low P-score. In addition, 33% of patients who experienced penetration at 6 months as well as those who experienced aspiration or penetration at 12 months after L had a minimum P-score. This observation confirms the major impairment of swallowing function for more solid consistencies and might suggest that penetration is not necessarily related to an increase in pharyngeal residue, but rather to a reduction in sensory inputs which might compromise the management of the bolus consistency and size during the swallowing act, with a subsequent intradeglutitory spill into the airways [39]. Of course, this is only an assumption that needs to be further examined.

However, in our experience, we observed an overall 3–7% pattern of aspiration after L and 10–14% after S, and among these patients, only 1 patient (3%) experienced clinical aspiration pneumonia which required hospitalization, protective tracheostomy, and antibiotic therapy. In this regard, we believe that a preventive (baseline) or a curative (post-treatment) prompt swallow therapy together with appropriate dietary counselling (mostly focused on appropriate consistencies) as well as proper nutritional support provided before, during, and soon after treatment (if necessary), might play an important role in reducing the pattern of clinical complications, as suggested by many authors [40–42].

Last but not least, despite the fact that our sample size did not allow a correlation between the dose delivered to the swallowing structures and the occurrence of a major event (such as severe pharyngeal retention or aspiration), the analysis of our data reported significantly higher doses (median doses > 50 Gy) received by the upper and middle constrictor muscles as well as by the base of the tongue as compared with the inferior constrictor muscle, cricopharyngeal muscle, and the whole larynx (median doses < 40 Gy). Therefore, a major radiation-related impairment of the upper SWAORs might have led to a reduction of the posterior movement of the tongue and of the cranio-caudal pharyngeal contraction, causing a reduced deglutition efficiency mostly for paste rather than for thin consistencies (supposing a different muscular effort of the different SWOARs for the propulsion of the different consistencies). On the contrary, a minor radiation-related impairment of the lower SWOARs (mostly larynx) might have preserved the protective mechanisms of airways closure, and this explains the very low pattern of aspiration reported in our study. Obviously, these statements need to be further confirmed by a more accurate analysis of the data on a larger sample size.

Conclusions

This present study reports results consistent with those reported by Feng et al. [36] in a similar larger mono-institutional prospective experience, showing ameliorative swallowing outcomes compared with the historical data obtained by using 3DCRT [25–28] or parotid-sparing IMRT [24, 33, 34, 37], despite being conducted on a selected patient population affected by tumors not causing substantial swallowing impairment at baseline. Moreover, a more severe swallowing dysfunction has clearly emerged for S rather than SS or L consistencies, which struggles to improve.

Therefore, we believe that our findings should be considered by clinicians for the dietary counseling of this subset of patients and suggest taking SWAORs into consideration (mostly for long-term survival HPV-positive patients) in the plan optimization process to maximally reduce irradiation without compromising target coverage.

Finally, more prospective studies reporting data on a larger sample size and on other HNC groups of patients will be necessary to find the limit of radiation doses to the swallowing structures.

Compliance with ethical guidelines

Conflict of interest Travel, congress, and course grants (Merck Serono, Nestlè, Kyowakirin) have to be declared for authors S. Ursino, S. Santopadre, V. Seccia, and B. Fattori. Travel, congress, and course grants (Merck Serono, Nestlè, Kyowakirin, Varian) have to be declared for author F. Paiar. P. Cocuzza, Durim Delishaj, A. Cristaudo, F. Pasqualetti, P. Giusti, R. Morganti, and F. Fiorica declare that they have no competing interests.

Ethical standards All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964

Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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