

Immediate effect of neuromuscular electrical stimulation on swallowing function in individuals after oral and oropharyngeal cancer therapy

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Abstract

Objective: To analyze the immediate effect of sensory and motor neuromuscular electrical stimulation, in oral and pharyngeal stages of swallowing, in individuals after oral and oropharyngeal cancer therapy.

Methods: The study was conducted on 10 individuals (mean age of 58 years) submitted to oral and oropharyngeal cancer therapy. The individuals were submitted to videofluoroscopy, during which they were randomly asked to swallow 5 mL of liquid, honey, and pudding, in three conditions: without stimulation, with sensory neuromuscular electrical stimulation, and with motor neuromuscular electrical stimulation. The degree of swallowing dysfunction was scored (Dysphagia Outcome and Severity Scale), as well as the presence of food stasis (Eisenhuber scale), and measurement of the oral and pharyngeal transit time. The results were statistically analyzed by the Friedman test or analysis of variance for repeated measures.

Results: The Dysphagia Outcome and Severity Scale revealed improvement for one individual with both sensory and motor stimuli, and worsening in two individuals, being one with motor and one with sensory stimulus. In the Eisenhuber scale, the neuromuscular electrical stimulation changed the presence of residues to variable extents. Concerning the oral and pharyngeal transit time, no difference was observed between the different stimulation levels for the consistencies tested ($p > 0.05$).

Conclusion: Both sensory and motor neuromuscular electrical stimulations presented a varied immediate impact on the oral and pharyngeal stages of swallowing in individuals after oral and oropharyngeal cancer therapy. Thus, the results of the immediate effect suggest that the technique is not indicated, evidencing the need of caution in the use of neuromuscular electrical stimulation for the rehabilitation of dysphagia, after HNC treatment.

Keywords

Head and neck neoplasms, deglutition disorders, chemotherapy, radiotherapy, electric stimulation

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Introduction

Dysphagia, involving increased oral and pharyngeal transit time (OTT and PTT), presence of residues and need of multiple swallows, such as change in laryngeal elevation and closure, impairs the efficiency and safety of swallowing.¹ Individuals treated for cancer in the oral cavity, pharynx, and larynx may present dysphagia, whose severity depends on the tumor size and location, affected structures, and type of treatment employed,² affecting the patient's quality of life and contributing to increased mortality by complications such as aspiration pneumonia, poor nutritional status, and respiratory failure.

The side effects of treatment of head and neck cancer commonly include deficits in swallowing that occur after surgical resection and may vary according to the tumor site,³ tumor size,⁴ extent of surgical resection,⁵ and possibly the

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type of reconstruction.⁶ In general, the greater the resection, the greater the impairment in the swallowing function. However, the resection of structures as the tongue, tongue base, and larynx have greater impact on the swallowing function,⁷ since these are vital structures for the formation and transition of the food bolus and airway protection.

Also, the literature indicates damages in tongue base retraction, slow closure of the laryngeal vestibule, bilateral pharyngeal weakness, reduced hyolaryngeal elevation, reduced cricopharyngeal opening,⁸ greater percentage of residues, laryngeal penetration, and laryngotracheal aspiration⁹ after treatment with chemoradiation, as well as abnormal pharyngeal contraction, increased PTT,¹⁰ impaired retraction of the tongue base,⁸ reduced laryngeal, and pharyngeal sensitivity^{10–13} after treatment with radiotherapy.

Several approaches have been suggested for the rehabilitation of oropharyngeal dysphagia in individuals after treatment for head and neck cancer (HNC), such as protective and enhancing swallowing maneuvers,^{14–16} utilization of vocal exercises,^{17,18} and orofacial myofunctional exercises,^{19–21} while neuromuscular electrical stimulation (NMES) is a relatively new modality for the treatment of dysphagia.

The authors found improved clinical outcomes in the group submitted to NMES associated with conventional therapy as compared with individuals receiving isolated conventional therapy in cases of oropharyngeal dysphagia, after treatment for HNC,²² and improved penetration and aspiration scale and rate of hyoid bone displacement in the group receiving functional electrical stimulation as compared to a home rehabilitation group.²³ Another study evidenced worse swallowing function after chemoradiotherapy, compared with the status before antineoplastic treatment, for two groups receiving different numbers of applications of NMES combined with conventional exercises, yet the group receiving higher number of NMES applications exhibited improved results of oral ingestion level.²⁴ Finally, a research revealed worse scores for the penetration and aspiration scale for the NMES group during regular swallowing associated with maneuvers, compared to that submitted to similar swallowing training with placebo stimulation.²⁵

The immediate physiological effect of NMES was studied in healthy individuals using 10 different positions of electrodes at the submental and laryngeal regions, one showing lowering of the hyoid bone and larynx at rest, as well as reduction of the peak of elevation of the larynx and hyoid bone during stimulated swallowing.²⁶ Another study using surface electric stimulation at the submandibular and laryngeal regions in individuals with oropharyngeal dysphagia observed lowering of the hyoid bone during stimulation, at rest, and reduced penetration and aspiration when sensorial stimulation was applied at low levels, yet this was not observed for motor electric stimulation.²⁷ Also, a study reported smaller pressure in the oropharynx and hypopharynx using NMES on the submental muscle region during swallowing in healthy individuals.²⁸

Considering the lack of consensus on the results of NMES in HNC population, one hypothesis of this study was that NMES changes the signs of oropharyngeal dysphagia, depending on the stimulation level applied and electrodes placement, in individuals submitted to oral and oropharyngeal cancer treatment.

Thus, this study analyzed the immediate effect of sensory and motor NMES in the oral and pharyngeal stages of swallowing in individuals after oral and oropharyngeal cancer treatment in order to understand the role of this treatment modality, in dysphagia.

Methodology

Sample

Ten adult and elderly individuals, median age of 58 years, nine male and one female, participated in this interventional cross-sectional study. Initially, the calculated sample size was 30 patients; however, only 10 individuals participated, because many did not return in the established period for data collection, due to impaired status, tumor relapse, financial problems, distance between their city of origin and the site of attendance, or even death.

The recruited individuals were clearly informed on the use of their data and signed an informed consent form. This study was approved by the Institutional Review Board, with protocol number CAAE 43930215.0.0000.5417.

The inclusion criteria were previous clinical evaluation of swallowing and signs and symptoms of oropharyngeal dysphagia, assessed by the same methodology for all participants, previous medical evaluation stating stable clinical conditions, completion of oral and oropharyngeal cancer treatment at least 3 months earlier, and regular dental follow-up.

The exclusion criteria comprised iodine therapy, presence of oral mucositis, more than one surgical procedure, total laryngectomy, rehabilitation with palatal prosthesis or swallowing rehabilitation with NMES, diagnosis of neurological disease, medical report of disease relapse or metastasis, and/or inability to perform the evaluation procedures proposed.

NMES

Electrical stimulation was applied to all individuals during videofluoroscopy of swallowing, revealing the immediate effect of sensory and motor NMES on swallowing. A two-channel system with current pulse at a fixed pulse rate of 80 Hz and pulse duration of 700 μ s (VitalStim, model 5900, Chattanooga Group) was used. Before placement of electrodes on the skin, the anterior neck region was cleaned with gauze and alcohol. They were positioned during different tasks, as suggested in the literature,²⁹ one channel being horizontally aligned above the hyoid bone (at the region of the mylohyoid muscle) and the other, horizontally, between the

hyoid bone and thyroid cartilage, inferiorly and slightly medial to the posterior horn of the hyoid bone (at the thyrohyoid muscle region).

The sensory and motor amplitude levels were determined before analysis of swallowing. Each participant was asked to describe the sensation triggered by stimulation, while the amplitude was increased in 0.5 mA, beginning from 0, until reaching the maximum tolerance level. The sensory level applied was 2 mA below the motor level (sensation of throat pressure or pulling of neck muscles), while the motor level was established at 2 mA below the maximum tolerance level.²⁹

Videofluoroscopy of swallowing

Videofluoroscopy examination was performed by a speech therapist trained in dysphagia, in the presence of a physician and an X-ray technician, to assess the dynamics of swallowing in different stimulation conditions (NMES). The exam was performed in a C-arm machine comprising a closed TV circuit, an X-ray machine with an image intensifier, and a video recording system (Arco Cirúrgico BV—Libra, Philips), which records 30 frames per second.

During examination, individuals were kept seated, and swallowing was analyzed in a lateral view. The anatomical limits for observation of videofluoroscopic images were the superior and inferior ones, encompassing the oral cavity to the esophagus, in which the lips were observed anteriorly; pharyngeal wall, posteriorly; nasopharynx, superiorly; and cervical esophagus, inferiorly.³⁰

The following foods were swallowed with contrast (Bariogel[®]): 5 mL of pudding food (thick paste), 5 mL of honey (thin paste), and 5 mL of liquid (water).³¹ All foods were dispensed using a disposable syringe directly into the individual's mouth. Pudding was prepared in a plastic cup by mixing 35 mL of filtered water, 2 g of powdered diet grape drink (Clight[®]), 25 mL of contrast, and 10 mL of food thickener (Hormel Thick & Easy[™]). Honey, with 35 mL of filtered water, 5 mL of thickener, 2 g of powdered diet grape drink (Clight[®]) and 25 mL of contrast; liquid, with 30 mL of water and 30 mL of contrast.

During videofluoroscopy of swallowing, the sequence of stimuli (zero amplitude, sensory, and motor) was randomly selected, allowing a 1-min interval between the different stimulation levels. The consistencies (liquid, honey, and pudding) were also randomly offered within each stimulation level, by randomization generated in the Excel software. Therefore, nine swallows were analyzed for each individual (3 stimulation levels \times 3 consistencies), using the scales.

The degree of swallowing dysfunction for each NMES level was assessed by the Dysphagia Outcome and Severity Scale (DOSS),³² which scores the degree of dysphagia in levels, from 7 (normal in all situations) to 1 (severe dysphagia).

The Eisenhuber scale, previously used in studies on patients with HNC,^{33,34} which considers the total height of the structure analyzed and scores as level 1 (mild—residue in less than 25% of the structure height), level 2 (moderate—residue in more than 25% yet less than 50% of the structure height), level 3 (severe—residues exceeding 50% of the structure height),³³ was applied. Stasis was considered as residues of food bolus surpassing the limit exceeding a thin layer of lining of structures or a line of barium after the first swallowing.³³ These residues were classified after the return of hyoid bone to the rest position, as suggested by Hind et al.³⁵ Stasis was evaluated in the following structures: oral cavity, valleculae, posterior pharyngeal wall, pyriform sinuses, and superior esophageal sphincter,³⁵ while swallowing pudding, honey, and liquid consistencies.

The OTT and PTT for each food offered, at the different NMES levels, were calculated by analysis of videos, using markers of the video editing software Kinovea v. 0.8.15 (Copyright[©] 2006–2011—Joan Charmant & Contrib.), which allows analysis of up to 30 frames per second. The OTT was calculated after identifying the first picture in which there was movement of the food bolus upon command, until the first picture in which the first border of bolus reached the posterior part of the mandibular ramus. The PTT was measured from the first picture in which the first border of bolus reached the posterior part of the mandibular ramus up to the first picture in which the bolus end crossed the superior esophageal sphincter.³⁶

Data analysis and statistical tests

Data collected by instrumental evaluation of swallowing were randomly distributed to an examiner, specialist and PhD in oropharyngeal dysphagia, with clinical experience and scientific training, who analyzed the examinations unaware of the stimulation level applied, thus, being considered a blinded examiner. This examiner classified the degree of swallowing dysfunction, applied the residues and measured the OTT and PTT. She analyzed 100% of samples and later 20% of examinations, randomly selected to analyze the intra-examiner agreement.

Intra-examiner agreement was assessed by Kappa statistics and method error (systematic and casual error). Almost perfect agreement was achieved ($\kappa=1.00$) for the DOSS, as well as fair-to-almost-perfect agreement, for the residues scale ($\kappa=0.33-1.00$), according to Landis and Koch.³⁷ Finally, the method error was calculated for the OTT and PTT, achieving systematic error values (paired t) $p > 0.314-0.783$ (p-values greater than 0.05 indicate good calibration of the examiner).³⁸ Analysis of the casual error (Dahlberg) revealed values from 0.09 to 0.43, in which values closer to zero indicate little disagreement of the examiner.³⁹

For comparison of videofluoroscopy results, considering the three stimuli applied, the statistical analysis by the Friedman test or analysis of variance for repeated measures

Individual	Gender	Age	Medical diagnosis	Treatment	Time between treatment and evaluation
1	M	52	SCC of tongue base	CT+RT+CL	17 months
2	M	66	SCC of the tonsillar pillar on the right side	RT+ CL	41 months
3	F	66	Cystic adenoid carcinoma in parapharyngeal space on the left side	SR+RT+CL	18 months
4	M	57	SCC on right lateral edge of the tongue	SR+CL	7 months
5	M	70	SCC of tongue	SR+RT+CL	11 months
6	M	58	SCC of retromolar area on the right side	RT+CT	23 months
7	M	52	SCC of tongue	SR+RT+CT+CL	8 months
8	M	50	SCC of tongue pelvis	SR+CL+RT	5 months
9	M	64	Tonsillar neoplasm on the left side	SR+RT+CL	36 months
10	M	46	SCC of the tonsil on the left side	RT+CT	16 months
n = 10	F = 01 M = 09	Median = 58			

Chart 1. Data concerning gender, mean age, cancer anatomical region, and treatment.

M: male; F: female; SR: surgery; RT: radiotherapy; CT: chemotherapy; CL: cervical lymphadenectomy; SCC: squamous cell carcinoma.

Table 1. Results obtained for the degree of oropharyngeal dysphagia according to the DOSS in the different levels of NMES applied.

Individual	DOSS		
	No stimulation	Sensory stimulation	Motor stimulation
1	6	6	5
2	6	6	6
3	6	6	6
4	6	6	6
5	6	5	6
6	6	6	6
7	6	6	6
8	4	5	5
9	6	6	6
10	6	6	6

DOSS: Dysphagia Outcome and Severity Scale; NMES: neuromuscular electrical stimulation.

(according to data distribution) was performed. All tests were applied at a significance level of 5%.

Results

Ten individuals were selected for analysis on this study. Information about the patients, considering the primary tumor location, type of treatment, and time between completion of cancer treatment and the swallowing videofluoroscopy examination are presented in Chart 1.

The sample comprised 10 patients with mild-to-moderate dysphagia, among which 9% (n=1) were female and most were male (91%, n=10), and the mean age of individuals was 59 years with median of 59 years. The tumor location consisted in 60% (n=6) oral cancer and 40% (n=4)

oropharyngeal cancer. The mean time between completion of antineoplastic treatment and accomplishment of swallowing videofluoroscopy examination was 1 year 5 months. Concerning the type of treatment, most participants (60%, n=6) received radiotherapy + surgery, combined with chemotherapy and/or cervical emptying, 30% (n=3) received radiotherapy + chemotherapy and/or cervical emptying, and finally, 10% (n=1) received isolated surgery. For patients who underwent surgery, information regarding the type and extent of surgical resection and/or reconstruction was not available/retrievable, due to lack of access to information on the medical records, which were located in other health units outside the university where the study was conducted.

Table 1 shows the effect of NMES on the degree of oropharyngeal dysphagia. Three, out of 10 individuals, presented

Table 2. Results obtained by the Eisenhuber scale, considering the different consistencies offered during application of sensory stimulation.

Individual	Consistency	Eisenhuber scale									
		Oral cavity		Valleculae		Pyriform sinuses		PPW		SES	
		NS	SS	NS	SS	NS	SS	NS	SS	NS	SS
1	Pudding	1	1	2	2	0	0	2	2	3	3
	Honey	1	1	1	1	0	0	0	0	3	3
	Liquid	1	1	0	0	0	0	0	0	2	2
2	Pudding	1	1	3	3	2	2	3	2+	2	1+
	Honey	1	1	2	2	1	1	2	3-	1	2-
	Liquid	1	1	1	3-	1	0+	3	1+	1	2-
3	Pudding	1	1	1	1	0	0	1	1	0	0
	Honey	1	1	2	1+	0	0	1	2-	0	0
	Liquid	1	1	1	1	0	0	1	1	0	0
4	Pudding	1	1	1	2-	0	0	0	0	1	2-
	Honey	1	1	1	2-	0	0	0	2-	1	1
	Liquid	1	1	2	2	0	1-	0	1-	1	1
5	Pudding	1	1	2	2	0	0	0	0	2	1+
	Honey	1	1	1	2-	0	0	0	0	1	1
	Liquid	1	1	1	1	0	0	0	0	1	0+
6	Pudding	1	1	0	1-	0	0	0	1-	0	1-
	Honey	1	1	0	1-	0	0	0	1-	0	1-
	Liquid	1	1	1	1	0	0	1	1	0	1-
7	Pudding	1	2-	2	2	1	0+	1	1	3	3
	Honey	1	1	1	1	1	0+	1	1	2	3-
	Liquid	1	1	1	1	1	0+	0	0	2	1+
8	Pudding	1	1	3	3	0	1-	1	1	1	3-
	Honey	1	1	3	3	0	0	1	2-	1	1
	Liquid	1	1	2	3-	1	1	3	2+	1	1
9	Pudding	1	1	2	3-	0	0	2	1+	2	1+
	Honey	1	1	2	1+	0	0	2	1+	1	1
	Liquid	1	1	1	1	0	0	0	0	1	0+
10	Pudding	1	2-	3	3	0	0	0	1-	1	1
	Honey	1	2-	1	3-	0	0	1	1	1	0+
	Liquid	1	2-	1	1	0	0	1	0+	1	1

PPW: posterior pharyngeal wall; SES: superior esophageal sphincter; NS: no stimulation; SS: sensory stimulation; + improved; - worsened.

changes in the swallow level, two worsened and one improved. Statistical analysis considering data of the DOSS did not reveal a significant difference ($p=0.78$) for the different stimulation levels applied.

Table 2 presents the results of evaluation of food stasis by application of the Eisenhuber scale for individuals submitted to sensory NMES, considering the different consistencies, as well as the structures analyzed. Findings on the residues scale for each individual varied for the different structures, except for the oral cavity and pyriform sinuses. In the oral cavity, application of sensory stimulus yielded an increase in residues for two individuals during assessment of pudding consistency in both, and for all consistencies in one of them. On the pyriform sinuses, changes were observed for four individuals, in general, improving for two and worsening for the others.

Table 3 exhibits the results of food stasis according to the Eisenhuber scale for individuals submitted to motor NMES, considering the different consistencies, as well as structures analyzed. No change was observed in the presence of residues for the oral cavity, while varied results were observed for the other structures. No change in the presence of residues in the oral cavity was observed for all 10 individuals. In the pyriform sinuses, there were no changes for six individuals, improvement for two and worsening for the other two, while varied results were observed for the other structures.

Descriptive values in the scoring of food stasis, considering the different structures, consistencies and NMES levels for the 10 cases of oral cancer, as well as the result of statistical analysis considering the different stimulation levels for each structure analyzed, are shown in Table 4. No significant difference was found ($p > 0.05$).

Table 3. Results obtained by the Eisenhuber scale, considering the different consistencies offered during application of motor stimulation.

Individual	Consistency	Eisenhuber scale									
		Oral cavity		Valleculae		Pyriform sinuses		PPW		SES	
		NS	MS	NS	MS	NS	MS	NS	MS	NS	MS
1	Pudding	1	1	2	2	0	0	2	2	3	3
	Honey	1	1	1	1	0	0	0	0	3	3
	Liquid	1	1	0	0	0	0	0	0	2	0+
2	Pudding	1	1	3	3	2	0+	3	2+	2	2
	Honey	1	1	2	2	1	0+	2	1+	1	1
	Liquid	1	1	1	2-	1	1	3	3	1	1
3	Pudding	1	1	1	3-	0	0	1	3-	0	0
	Honey	1	1	2	3-	0	0	1	1	0	0
	Liquid	1	1	1	1	0	0	1	3-	0	0
4	Pudding	1	1	1	1	0	0	0	0	1	1
	Honey	1	1	1	1	0	0	0	0	1	1
	Liquid	1	1	2	2	0	1-	0	0	1	1
5	Pudding	1	1	2	2	0	0	0	0	2	1+
	Honey	1	1	1	1	0	0	0	0	1	1
	Liquid	1	1	1	1	0	0	0	0	1	1
6	Pudding	1	1	0	2-	0	0	0	0	0	0
	Honey	1	1	0	0	0	0	0	0	0	0
	Liquid	1	1	1	0+	0	0	1	0+	0	0
7	Pudding	1	1	2	1+	1	0+	1	1	3	1+
	Honey	1	1	1	1	1	1	1	1	2	2
	Liquid	1	1	1	1	1	1	0	1-	2	2
8	Pudding	1	1	3	1+	0	1-	1	1	1	2-
	Honey	1	1	3	2+	0	0	1	1	1	1
	Liquid	1	1	2	2	1	0+	3	1+	1	2-
9	Pudding	1	1	2	3-	0	0	2	2	2	3-
	Honey	1	1	2	2	0	0	2	2	1	2-
	Liquid	1	1	1	1	0	0	0	2-	1	1
10	Pudding	1	1	3	3	0	0	0	0	1	1
	Honey	1	1	1	3-	0	0	1	0+	1	0+
	Liquid	1	1	1	3-	0	0	1	0+	1	0+

PPW: posterior pharyngeal wall; SES: superior esophageal sphincter; NS: no stimulation; SS: sensory stimulation; MS: motor stimulation; + improved; - worsened.

Table 5 shows the OTT and PTT, considering the different stimuli applied and consistencies tested, revealing that NMES promoted different variations in transit times for the different individuals.

Table 6 presents the mean, standard deviation, median, first and third quartiles for OTT and PTT, as well as “p” values of comparison between the different NMES levels, for all consistencies analyzed. The results revealed little variation in OTT and PTT, considering the sensory and motor stimulation levels. Statistical analysis did not reveal significant difference for the different NMES levels for all consistencies ($p > 0.05$). However, the results revealed a high standard deviation, especially for the OTTs.

Discussion

This is the first study aiming to investigate the immediate effect of NMES on the swallowing function in individuals

submitted to oral and oropharyngeal cancer treatment. The hypothesis was that there would be a reduction in the signs of oropharyngeal dysphagia in this population, with different responses to the different stimulation levels. However, these results were not accomplished.

Before NMES, nine individuals presented score 6 on the DOSS, indicating swallowing with functional limitations, in disagreement with Lin et al.,²³ in which all participants should present score below 6 on the same scale to be included in the study. The present research considered as inclusion criteria the presence of signs and symptoms of oropharyngeal dysphagia, as confirmed by instrumental examination. However, classification of the DOSS, obtained in this study, might be explained by the spontaneous improvement in swallowing of these individuals after treatment for HNC. A previous study revealed improved swallowing function along 18 months after treatment, using a specific chemoradiotherapy protocol in individuals with HNC.⁴⁰ Improvement

Table 4. Values of food stasis in the different levels of NMES for the different consistencies tested, with median or mean and standard deviation.

	Eisenhuber scale											
	Pudding				Honey				Liquid			
	NS	SS	MS	p value	NS	SS	MS	p value	NS	SS	MS	p value
	Median or mean ± SD				Median or mean ± SD				Median or mean ± SD			
Oral cavity	1.00	1.00	1.00	0.14	1.00	1.00	1.00	0.37	1.00	1.00	1.00	0.37
Valleculae	1.90 ± 0.99	2.20 ± 0.79	2.10 ± 0.88	0.63	1.40 ± 0.84	1.70 ± 0.82	1.60 ± 0.97	0.58	1.00	1.00	1.00	0.37
Pyriiform sinuses	0.00	0.00	0.00	0.72	0.00	0.00	0.00	0.61	0.00	0.00	0.00	0.78
PPW	1.00	1.00	1.00	1.00	0.80 ± 0.79	1.30 ± 0.95	0.60 ± 0.70	0.03	1.00 ± 1.25	0.60 ± 0.70	1.00 ± 1.25	0.53
SES	1.50 ± 1.08	1.50 ± 1.18	1.40 ± 1.08	0.95	1.00	1.00	1.00	0.45	1.00 ± 0.67	0.90 ± 0.74	0.80 ± 0.79	0.78

NMES: neuromuscular electrical stimulation; NS: no stimulation; SS: sensory stimulation; MS: motor stimulation; PPW: posterior pharyngeal wall; SES: superior esophageal sphincter; SD: standard deviation.

in dysphagia was also observed in individuals in another study,⁴¹ at 3 and 12 months posttreatment, yet the participants were submitted to isolated radiotherapy.

This study evidenced that NMES led to worsening on the DOSS for two individuals, being one with motor and one with sensory stimulus, and only one individual improved in both stimulations, which might be explained by the fact that this individual was the only one presenting diagnosis of mild-to-moderate oropharyngeal dysphagia, according to the DOSS. The positive result observed for one individual corroborates a previous study⁴² that evidenced improvement in the severity of dysphagia after therapy with NMES in individuals with mild-to-moderate oropharyngeal dysphagia, of different etiologies, including cases of HNC. Thus, it is important to consider the methodological differences, since this study investigated the immediate effect, without any therapeutic process. The worse swallowing may be explained by the possible reduction in the hyolaryngeal elevation during swallowing²⁶ for the individual receiving motor NMES and presenting functional swallowing (individual number 1), and because the sensory stimulation applied may have yielded dysfunctional motor responses, due to possible sensory-motor deficits related to aging⁴³ and/or radiotherapy² for individual number 5.

Analysis of residues during sensory stimulation revealed varied results for the different individuals, considering the structures analyzed, and statistical analysis did not reveal a difference for the findings in the different conditions. No studies were found applying the sensory stimulus in individuals with mechanical dysphagia, thus precluding the comparison of results. It would be expected that the increased sensory input improves the motor responses involved in the swallowing process, thus, with a smaller occurrence of residue.

Also, concerning the Eisenhuber scale, motor stimulation promoted different responses, without a statistically significant difference, as compared to the condition with no stimulation. Different from this study, a previous investigation reported a reduced stasis in pyriform sinuses, and the authors mentioned that functional electrical stimulation may increase the rate of hyoid bone movement and reduce the stasis in pyriform sinuses.²³ The lack of agreement between the present findings and Lin et al.²³ may be explained by methodological differences, especially concerning the different modalities of electrostimulation applied.

With regard to the OTTs, a variability was seen in the results obtained for the oral stage, considering the different NMES levels. In the pharyngeal stage, there was a reduction in transit time (close to 1 s) for two individuals and increase for the other two, one of whom exhibited a reduction in PTT, for both sensory and motor stimulations. Thus, no statistically significant differences were found for both stimulations, for all consistencies analyzed. Lin et al.²³ revealed similar outcomes, with no statistically significant differences before and after therapy, despite the p=0.056 for comparison

Table 5. Results (in seconds) of the oral and pharyngeal transit times in the different consistencies tested and NMES levels applied.

Individual	Consistency	Oral transit time (s)			Pharyngeal transit time (s)		
		NS	SS	MS	NS	SS	MS
1	Pudding	1.80	2.46	1.66	2.33	1.23	2.43
	Honey	1.40	1.03	1.13	0.73	0.70	0.80
	Liquid	0.83	0.60	0.60	0.86	0.70	1.06
2	Pudding	1.66	0.93	0.63	0.60	0.66	0.70
	Honey	1.43	0.70	1.81	0.70	0.66	0.60
	Liquid	0.53	1.50	1.66	0.66	0.66	0.70
3	Pudding	0.73	2.20	1.23	1.33	0.93	1.46
	Honey	2.93	1.83	0.50	1.00	1.06	0.96
	Liquid	1.33	0.53	0.43	1.06	1.36	1.23
4	Pudding	3.16	2.50	2.22	1.03	0.80	1.30
	Honey	0.83	0.70	0.46	0.90	0.73	0.76
	Liquid	0.56	0.46	0.86	0.83	0.83	0.93
5	Pudding	1.76	3.00	3.70	0.86	1.00	0.70
	Honey	1.90	1.10	3.23	0.70	0.80	0.73
	Liquid	1.46	2.70	0.86	1.03	1.00	0.86
6	Pudding	2.56	1.50	1.13	0.86	1.36	1.03
	Honey	1.43	0.93	1.00	0.80	0.80	0.70
	Liquid	0.63	0.70	0.80	0.80	0.80	0.83
7	Pudding	0.76	0.90	0.83	1.80	1.33	2.20
	Honey	1.03	0.46	1.13	0.76	0.76	1.76
	Liquid	0.56	0.36	0.46	0.53	0.86	1.43
8	Pudding	2.16	1.93	1.43	1.50	0.90	1.26
	Honey	2.06	0.70	1.36	1.13	0.86	1.30
	Liquid	1.30	1.10	0.40	1.23	0.83	1.86
9	Pudding	2.13	2.10	2.60	0.96	0.90	0.63
	Honey	1.20	3.77	2.43	0.90	0.90	0.66
	Liquid	2.03	1.56	1.80	0.86	0.83	0.60
10	Pudding	0.46	1.00	0.76	2.26	0.80	0.83
	Honey	0.76	0.90	0.90	0.83	1.26	0.63
	Liquid	0.46	0.56	0.76	0.90	0.90	0.86

NMES: neuromuscular electrical stimulation; NS: no stimulation; SS: sensory stimulation; MS: motor stimulation.

of OTT, which might be explained by the reduced sample, as in this study.

This study demonstrated that NMES did not change the OTT and PTT, neither the degree of dysphagia and penetration/aspiration for most individuals, besides presenting a varied immediate impact in relation to the presence of residues. Few studies were found in the literature using NMES after HNC to treat dysphagia, lacking consensus on the results of NMES application in this population, which impairs the application of this technique in the clinical practice. Also, it should be considered that, theoretically, NMES is indicated for cases with neuromuscular disturbances secondary to central nervous system disorders,⁴⁴ which is not the case of HNC individuals, thus raising doubts concerning the use of this technique for this population.

It is important to consider the methodological differences between the aforementioned reports and this study concerning the stimulation and evaluation methods, since individuals in this study were submitted to the immediate effect of

NMES, different from most reports in the literature, which investigated the effect of different modalities of electrostimulation combined with conventional therapy.

Even though the physiopathology of oral cancer is focused on the alteration of oral motor propulsion caused by muscle loss, the sensorial stimulation may increase the sensitive afferent information, triggering a motor response, since electrodes in the suprahyoid region may stimulate the mouth floor region and the laryngeal musculature, stimulate the brain region in charge of swallowing, and thus enhance the intentional movement of structures that are controlled by these muscles. Since the motor stimulus has the ability to activate the remaining muscle groups, which persisted after surgery, this leads the individual to search for adjustments to perform the function, and it is possible to produce accurate movements, since the nervous system is adaptable. This adaptable nervous system recognizes its limitations and may continuously compensate them to avoid systematic errors in movement.⁴⁵⁻⁴⁷

Table 6. Values (in seconds) of mean, standard deviation, median, first and third quartiles and p values of oral and pharyngeal transit time, for all consistencies evaluated in the different NMES levels.

	No stimulation				Sensory stimulation				Motor stimulation				p value	
	Mean	SD	Median	Third quartile	Mean	SD	Median	Third quartile	Mean	SD	Median	Third quartile		
	OTT	Pudding	1.72	0.86	—	—	—	—	—	1.62	0.97	—		—
	Honey	—	—	1.40	1.00	—	—	—	—	—	0.90	0.70	—	0.20
	Liquid	0.97	0.53	—	—	1.01	0.73	—	0.86	0.49	—	—	—	0.76
PTT	Pudding	1.35	0.61	—	—	0.99	0.24	—	1.25	0.63	—	—	—	0.12
	Honey	—	—	0.82	0.72	—	—	0.80	0.72	—	—	0.75	0.65	0.70
	Liquid	0.88	0.20	—	—	0.88	0.19	—	1.04	0.38	—	—	—	0.23

NMES: neuromuscular electrical stimulation; SD: standard deviation; OTT: oral transit time; PTT: pharyngeal transit time.

Among the limitations of this study, it is important to emphasize the functional swallowing on the DOSS exhibited by most individuals, lack of detailed information concerning the medical treatment, such as surgery, radiotherapy, and chemotherapy, due to lack of access to information on the medical records, which were located in other health units outside the university where the study was conducted, it was not possible to calculate the sample size in this study, the reduced sample, owing to the inclusion and exclusion criteria adopted, as well as the great number of individuals that died or presented cancer relapse.

This study aimed to understand the immediate effect of NMES on the swallowing function in individuals after oral cancer treatment. The results demonstrated the importance of achieving information before applying this therapeutic resource, considering the impact on the pathophysiology of swallowing, the actual achievement of benefits for the individual, and the safe use of the technique. Therefore, clinical studies using different positioning of electrodes, with different analyses of results, such as duration of laryngeal elevation, with larger and more homogeneous samples, concerning gender, age, site of cancer and treatment modalities, are necessary to elucidate the effects of NMES on dysphagia in individuals submitted to treatment for HNC.

Conclusion

Both sensory and motor NMES presented a varied immediate impact on the oral and pharyngeal stages of swallowing in individuals after oral and oropharyngeal cancer therapy, concerning the degree of dysphagia, presence of residues, without affecting the OTT and PTT. Thus, the results of the immediate effect suggest that the technique is not indicated, evidencing the need of caution in the use of NMES for the rehabilitation of dysphagia, after HNC treatment.

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Author contributions

D.R.C. participated in the project creation, data collection and interpretation, and the article writing. C.M.F.R. participated in the patient selection and in the revision of the final version of the article. P.S.d.S.S. participated in the patient selection and in the revision of the final version of the article. G.B.-F. participated in the project creation, data interpretation, and article writing, as evaluator.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval

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Informed consent

Written informed consent was obtained from all subjects before the study.

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