Case Report

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TENS on salivary flow and voice

Efeito da TENS no fluxo salivar e voz

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ABSTRACT

Electrical stimulation has shown potential in improving salivary flow in patients with head and neck cancer, but its impact on post-radiotherapy voice is not yet fully understood. This is a case series involving three men and one woman with an average age of 58 years and 2.5 months, who underwent chemotherapy and radiotherapy for oropharyngeal tumors, presenting with vocal complaints and hyposalivation. All subjects underwent nasofibrolaryngoscopy, voice recording, and salivary flow measurement at the beginning and end of treatment. Perceptual-auditory and acoustic voice analyses were performed. The aim was to compare the results of salivary volume and vocal measures before and after electrical stimulation. After the intervention, there was a variable increase in salivary flow in all patients, with an average of 0.66 ml/min; however, no marked differences were observed in the perceptual-auditory voice evaluation, as they were very subtle. Nevertheless, changes were recorded in the acoustic analysis of glottal source (changes in fundamental frequency, with a more evident increase, and reduction in some parameters) and in the spectrographic analysis using Wide Band Spectrography. Improvement was observed, with a reduction in antiresonance at low and high frequencies. In Narrow Band Spectrography, there was a worsening, with a reduction in the definition and regularity of harmonics at low and mid frequencies and across the entire spectrogram, as well as a reduction in the number of harmonics at mid frequencies and across the entire spectrogram. Improvement was recorded with a reduction in noise (general) and sub-harmonics at high frequencies. Electrical stimulation demonstrated the ability to induce a variable increase in salivary flow with some acoustic vocal improvements, while the perceptual-auditory voice evaluation did not reveal differences between pre- and post-intervention moments. Despite the promising results, studies with larger samples and greater control of intervening variables are crucial to establish a causal relationship between saliva induced by electrical stimulation and the improvement of vocal quality in patients undergoing radiotherapy.

Keyword: Transcutaneous electric nerve stimulation; Head and neck neoplasms; Xerostomia; Radiotherapy; Voice

RESUMO

A Eletroestimulação tem mostrado potencial na melhora do fluxo salivar em pacientes com câncer de cabeça e pescoço, mas seu impacto na voz pós-radioterapia ainda não é totalmente compreendido. Esta é uma série de casos, com três homens e uma mulher com média de idade de 58 anos e 2.5 meses, submetidos à quimioterapia e radioterapia para tumor de orofaringe, com queixa vocal e de hipossalivação. Todos os sujeitos foram submetidos à nasofibrolaringoscopia, registro das vozes e medida do fluxo salivar no início e no final do tratamento. Foram realizadas análises vocais perceptivo-auditiva e acústica. O objetivo foi comparar os resultados do volume de saliva e de medidas vocais antes e após a eletroestimulação. Após a intervenção, houve aumento variável no fluxo salivar em todos os pacientes, com média de 0.66 ml/min, porém, não foram observadas diferenças marcantes na avaliação perceptivo-auditiva da voz, por serem muito sutis. No entanto, foram registradas mudanças na análise vocal acústica de fonte glótica (mudanças na frequência fundamental, com aumento mais evidente, e redução em alguns parâmetros) e espectrográfica na Espectrografia de Banda Larga. Observou-se melhora, com redução da antirressonância, em baixas e altas frequências. Na Espectrografia de Banda Estreita, houve piora, com redução da definição e regularidade dos harmônicos nas frequências baixas e médias e em todo o espectrograma, e com redução do número de harmônicos nas frequências médias e em todo o espectrograma. Registrou-se melhora com redução de ruído (geral) e de sub-harmônicos em altas frequências. A eletroestimulação demonstrou induzir aumento variável no fluxo salivar com algumas melhoras vocais acústicas, enquanto a avaliação vocal perceptivo-auditiva não revelou diferenças entre os momentos pré e pós-intervenção. Apesar dos resultados promissores, estudos com amostras maiores e maior controle de variáveis intervenientes são cruciais para estabelecer uma relação causal entre a saliva induzida por eletroestimulação e a melhora da qualidade vocal em pacientes submetidos à radioterapia.

Descritores: Estimulação elétrica nervosa transcutânea; Neoplasias de cabeça e pescoço; Xerostomia; Radioterapia; Voz

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INTRODUCTION

Head and neck cancer (HNC) affects millions of people worldwide. Upon diagnosis, patients may undergo single or combined treatments, including surgery, chemotherapy (CT) and/or radiotherapy (RT)[1]. Due to the functions performed in this region, patients with HNC may present deviations in swallowing, chewing, breathing, speech, and voice[2]. The severity of these deviations depends on the location and treatment of HNC, impacting the individual's quality of life to varying degrees[2].

Communication, through the synergy between speech and voice, is one of the most powerful tools for social interaction and plays an important role in the patient's daily life and in maintaining their activities of daily living[3]. Tumors of the oral cavity and oropharynx, when involving surgery or irradiation of the suprahyoid muscles, can compromise the superior movement of the larynx, causing external rotation of the cricothyroid joint. These movements distort the force vectors, tensing the intrinsic muscles of the larynx and thus increasing the fundamental frequency (fo)[3].

Furthermore, radiation alters the morphology of skeletal muscles, limiting their contractility capacity and directly interfering with muscle mobility due to fibrosis and stiffness[4]. In the voice, this means increased pitch, reduced loudness, and a significant increase in tension, roughness, and harshness[5]. Hyposalivation, present in most cases treated with radiation, is an exacerbating factor for these characteristics. This condition occurs from 26-39 Gy (Gray), when the salivary glands (major and minor) are in the radiation field[4].

Saliva is essential for lubricating the oral cavity, digestive tract, and larynx[4]. There is evidence that small salivary glands are dispersed throughout the oral mucosa, digestive tract, and laryngeal inlet[4]. Reduced salivary flow can cause oral imbalance, manifested by altered taste perception, increased incidence of cavities and difficulties in chewing, swallowing and vocal production, due to insufficient lubrication of the phonatory tract[5,6]. Hyposalivation contributes to dryness of the vocal folds, erythema and laryngeal edema[7]. In addition, changes in vocal parameters are identified, suggesting differences in mass, size and tension between the vocal folds[7].

Xerostomia reduces the moisture content of the vocal tract mucosa, causing dehydration and dryness of the phonatory structures, which compromise the vibration mechanism of the vocal folds, resulting in deterioration of their quality and periodicity. This manifests through vocal characteristics such as hoarseness, breathiness, crackling, f_o instability, and vocal fatigue[5]. The vibration of the vocal fold mucosa is closely related to the viscosity of the saliva secreted by the glands of the laryngeal ventricle, which may imply greater or lesser effort required for voice production[5,6]. This change in viscosity directly impacts the movement of the vocal folds, reducing their amplitude and increasing the contact time during phonation. In addition, the biomechanical properties of the vocal folds and the resonance characteristics of the upper airways are also modified, resulting in changes in voice quality and production[8].

Treatments for xerostomia, usually palliative, include topical agents such as ice chips and saliva substitutes, increased water intake, application of lip balm, sugar-free gum, paraffin and citric acid-containing lozenges, and mouthwashes. Systemic sialogogues such as pilocarpine and cevimeline may be prescribed to stimulate saliva production, although they may cause side effects. In addition, complementary therapies such as acupuncture have shown the potential to improve the condition[9,10].

In addition to medications, through Transcutaneous Electric Nerve Stimulation (TENS), it is possible to increase blood circulation in the glandular region, stimulate the auriculotemporal nerve, which is secretomotor, and promote the dilation of functional acini, culminating in increased salivary flow. This resource has demonstrated potential in patients with HNC who presented hyposalivation induced by RT[8], with long-lasting effects.

No studies related to the effects of TENS on saliva and voice were found in the literature. However, a study conducted with healthy individuals found that the use of pilocarpine mouthwash with the aim of stimulating salivary flow enabled a significant increase in salivary flow. As a result, notable differences were observed in f_o, as well as in the increase in absolute and relative shimmer and in the coefficient of variation of amplitude, particularly among male participants[6].

TENS has demonstrated the potential to increase salivary flow. Its mechanism of action is believed to involve direct stimulation of the auriculotemporal nerve, which innervates the salivary glands. This neural stimulation can trigger a reflex, leading to increased salivary production. In addition, TENS can promote local vasodilation, improving blood flow to the salivary glands and enhancing its effects[6,9,11-13].

TENS has been studied for its effects on radiotherapy-induced hyposalivation for some years. In one study, TENS was shown to significantly improve stimulated salivary flow in patients with hyposalivation after radiotherapy. The study involved 68 patients, with those in the TENS group receiving eight sessions over four weeks. The results indicated a progressive increase in stimulated salivary flow (SSF) from the third session onwards, with significant improvements in self-perceived salivary flow and quality of life observed up to six months after treatment[8]. This is an example that makes up the publications related to the subject and has expanded the use of TENS as a resource for hyposalivation.

The International Society of Oral Oncology-Multinational Association for Supportive Care in Cancer (ISOO-MASCC) and American Society of Clinical Oncology (ASCO) guidelines also suggest that TENS may be offered to improve salivary gland hypofunction and xerostomia in post-radiation patients, although the quality of evidence is considered low and the strength of recommendation is weak[14]. Another study demonstrated that TENS can increase salivary flow during stimulation in post-irradiated patients, indicating its potential as a supportive care modality[15].

Although there are techniques aimed at increasing salivary flow, studies evaluating the relationship between saliva volume and vocal quality after RT in HNC are still scarce. The aim of this study was to present a series of HNC cases with hyposalivation after RT and to compare the results of saliva volume and objective and subjective vocal measures before and after TENS.

CLINICAL CASE PRESENTATION

This is a case series carried out in a database of a larger study, previously approved by the Human Research Ethics Committee of the institution of origin (n° 68866023.2.0000.5335). All participants received clarifications about their participation in the study and signed the Informed Consent Form.

For the selection of subjects, whose records were part of the database used in the present study, the history of RT for HNC (except larynx) was considered; minimum of 60 days after RT; adult individuals aged 18 years or older, both genders; absence of cancerous lesion in salivary glands (sublingual, submandibular and parotid) and complaint of xerostomia confirmed by evaluation of salivary flow (hyposalivation).

Excluded from the study: records of cases with active laryngeal disease confirmed by medical report; tumors that compromised velopharyngeal closure; oral breathers (organic and functional); use of glandular protective substances or salivary stimulants during or after RT and during the data collection period; stimulated salivary flow volume greater than 1 ml/minute; skin changes in the region where electrotherapy was applied or any other changes that contraindicated TENS; use of a pacemaker or any other devices that made TENS impossible; unavailability of time to participate in the study (twice/week for one month) and excessive absences throughout the treatment (more than 30% of the total sessions).

History and medical assessment

The volunteers' identity, health history and clinical condition data, such as the total radiation dose used and the time elapsed since the end of RT, were collected. The subjects also underwent medical evaluation and fiberoptic nasal laryngoscopy performed by a head and neck surgeon to rule out any possible recurrence of the disease. The patient's nostril was anesthetized with 2% xylestesin to minimize discomfort during the introduction of the optical fiber. Then, an Olympus Medical System Corp device was inserted through one of the nostrils. A Karl Storz telecamera (model DX II) and an Olympus light source (model CLV-S20) allowed detailed inspection of the upper aerodigestive tract, including the nasal cavity, rhinopharynx, oropharynx, hypopharynx and larynx.

To complement the examination, when necessary, direct oroscopy and palpation of the oral cavity were performed. These data were recorded in each patient's medical record.

Salivary flow measurement

Salivary flow was measured before and after TENS and determined using the sialometry technique, using the Halitus® kit. Participants were instructed not to eat or drink, smoke or perform oral hygiene for one hour before the evaluation. Volunteers were asked to chew a standardized silicone sialogogue for five minutes, without swallowing saliva, and place it in a millimeter tube. The choice of mechanical silicone sialogogues is justified by their ideal characteristics. They are non-toxic, inert to saliva, taste and odor, do not cause side effects, have a shape and hardness suitable for salivary stimulation, maintain their dimensions over time and can be sterilized[16,17]. To precipitate the foam and convert it into saliva, the drug dimethicone was used (three drops for 4 ml; four drops for 8 ml; five drops for more than 8 ml of foam). Each drop of dimethicone corresponded to 0.02 ml and this value was subtracted from the final result. Dimethicone, an antifoaming agent, allows rapid precipitation of salivary foam to be induced. The use of dimethicone allows all the foam to be accounted for in the test result, providing an effect that is faithful to the real saliva production. The volume of dimethicone added was carefully controlled and subtracted from the total volume of the sample, minimizing the impact of the substance on the results[16].

The amount of saliva and foam was quantified in milliliters (ml) and this value was divided by 5 to determine the flow in ml/minute. The following reference values were adopted: less than 0.7 ml/min (very low); 0.7-1 ml/min (low); greater than 1 ml/min (normal) for stimulated saliva (submandibular, sublingual and parotid)[16,18,19].

Voice samples

Voice samples were obtained in a silent room, with ambient noise below 48 dBNPS (RadioShack sound pressure meter), and the prolonged emission of the vowel /a/ was collected with the individual in an orthostatic position before and after the intervention[20].

To gather the voices, a digital recorder (Zoom H4n Pro digital Handy Recorder 4 channels) was used. It was configured at 96 kHz and 16 bits, with the input level adjusted to 50% of its maximum capacity, with a professional Behringer ECM8000 Omnidirectional microphone attached and placed at a 90º angle in relation to the mouth and 4 cm away for the sustained vowel and 10 cm for the connected speech samples[21]. The emission of the sustained vowel /a/ was performed at the patient's usual pitch and loudness, followed by deep inspiration and maintaining the maximum phonation time. Spontaneous speech occurred with the answer to the question “What do you think of your voice?” and the verbalization of the months of the year.

Intervention

To the best of the authors' knowledge, there are no studies relating saliva produced by TENS to voice characteristics in patients with radiation xerostomia. However, studies have demonstrated the effect of saliva production through TENS in these patients[8,15,22,23]. A systematic review confirms the safety and feasibility of TENS in the treatment of radiotherapy-induced xerostomia, suggesting that daily TENS therapy should be initiated simultaneously with radiotherapy for greater efficacy[24].

In this study, silicone electrodes were used to perform electrostimulation, adhered to the skin with micropore and placed bilaterally in the region of the parotid and submandibular glands. The device used was the Neurodyn II, with TENS current, frequency of 50 Hz and pulse width of 250 µs, for 20 minutes[8,23,25]. Two sessions were performed per week, for four weeks, totaling eight sessions. The intensity was graduated according to the maximum tolerance level, being increased until the end of twenty minutes and gradually adjusted every five seconds, until the patient indicated the maximum comfort level, signaling with the hand[8]. All data described were contained in the database. With the stored voice samples, the acoustic vocal analyses described below were performed.

Acoustic vocal assessment of glottal source

The analysis of the vocal characteristics of the glottal source was performed based on the sustained emission of the vowel /a/ before and after the intervention, stored in the database. The vowel /a/ was edited, eliminating the initial and final segments of the emission, due to the presence of natural instabilities. An analysis window of 3.6 s was standardized, taking as a basis the shortest time of sustaining the vowel observed among all participants.

Acoustic vocal measurements were obtained automatically using the Multi-Dimensional Voice Program Advanced (MDVPA) (Kay-PENTAX®, New Jersey, USA), configured with a 44 kHz sampling rate and 16-bit analog-to-digital conversion.

The measures used in this study were: frequency measures: f_o, Highest fo (fhi), Lowest f_o (flo), Standart Deviation of f_o (STD); fo disturbance measures: Absolute Jitter (Jita), Jitter Percent (Jitt), Relative Average Perturbation (RAP), Pitch Perturbation Quotient (PPQ), Smoothed Pitch Perturbation Quotient (sPPQ), f_o Variation (vf_o); amplitude disturbance measures: Shimmer in dB (ShdB), Shimmer Percent (Shim), Amplitude Perturbation Quotient (APQ), Smoothed Ampl.Perturbation Quotient (sAPQ), Peak-to-Peak Amplitude Variation (vAm); noise measurements: Noise to Harmonic Ratio (NHR), Voice Turbulence Index (VTI), Soft Phonation Index (SPI); voice break measurements: Degree of Voice Breaks (DVB), Number of Voice Breaks (NVB); measures of voiceless or unvoiced segments: Number of Unvoiced Segments (NUV), Degree of Voiceless (DUV); measures of subharmonic segments: Degree of Sub-harmonics (DSH), Number of Sub-harmonic Segments (NSH)[21,24].

Acoustic spectrographic voice evaluation

The vowel /a/, edited and used in the acoustic vocal evaluation of glottal source, was used for acoustic spectrographic analysis, through the Real-Time Spectrogram (RTS) program (Kay-PENTAX®, New Jersey, USA), configured with a capture rate of 11 kHz and 16-bit analog-to-digital conversion. The analysis was performed with Wideband Spectroscopy (100 points, 646 Hz) (WBS) and Narrowband Spectroscopy (1024 points, 63.09 Hz) (NBS). The analysis window was configured with the default duration of 3.6 s[20,21].

The graphic representations of the WBS and NBS captured before and after the intervention were subjected to a coding process and subsequent randomization. These randomized images were made available for individual analysis by three speech-language pathologists with doctorates, each with professional experience of at least a decade and expertise in the area of spectrographic acoustic analysis.

In order to ensure the objectivity of the analyses, the speech therapists who acted as judges were kept anonymous regarding the research objectives, information regarding gender, age and period (pre or post-TENS). They received the files by email, containing exclusively the WBS and NBS images, not including the sound recordings of the participants' voices.

The judges did not receive specific training to conduct this analysis; however, they were provided with model spectrographs that represented normality standards in order to guide their assessments. The judges used the Spectrographic Vocal Assessment Protocol (SVAP) to record their conclusions[21]. This protocol assessed several aspects of NBS and WBS, as described below.

Regarding the evaluation of the intensity of the trace, whether of the formants (F_m), low, medium and high frequencies, or the complete spectrogram, the SVAP presented a scale ranging from 0, representing the total absence of color in the spectrographic trace, to 10, maximum color intensity in the trace. The presence of noise was identified by the shaded or dotted areas in the spectrogram, where 0 denoted the complete absence of noise and 10 represented the maximum presence of noise (in the form of shaded areas) in the spectrographic trace[26,27].

Regarding the definition of F_m and harmonics (nf_o), their assessment was based on the visibility, demarcation and symmetry of the trace. In this context, the assessment scale ranged from 0, indicating total lack of definition, to 10, representing maximum definition of F_m and nf_o. The regularity of the trace was related to its continuity and stability, being scored from 0, corresponding to total irregularity, to 10, which reflected maximum regularity in the trace. The presence of subharmonics was characterized by the manifestation of traces between two consecutive nf_o, resulting in a complete or partial duplication of the nf_o. The scale used to assess the presence of subharmonics ranged from 0, indicating total absence of subharmonics, to 10, signaling the presence of subharmonics throughout the spectrogram. The F_m bandwidth (B_{Fm}) was assessed as 0, corresponding to totally reduced/absent, and 10, to totally increased[26].

The evaluations performed by the judges using the validated SVAP protocol were quantified numerically on a scale ranging from 0 to 100 mm. Afterwards, the average of the responses of the three judges in each aspect evaluated was calculated for each subject. The averages of each group before and after the intervention were calculated. The average results of each group were compared and discussed in relation to the other study variables.

Three judges performed the auditory-perceptual vocal assessment using the GRBASI scale[26]. The Grade (G) parameter assesses the general degree of vocal alteration; Roughness (R), the roughness of the voice; Breathiness (B), the breathiness; Astheny (A), the asthenia; Strain (S), the tension and Instability (I), the instability. The parameters are quantified in an intensity scoring system from 0 to 3 (0 - normal, 1 - mild, 2 - moderate and 3 - severe).

The judges received the voice files and a protocol defining the parameters and scoring to record their responses by email. As in PAVE, they were blinded to the research objective, age, gender, and time of intervention (pre or post). The agreement of at least two of the judges was the criterion used for each parameter. When there was no consensus among the judges, a fourth expert evaluator was needed to define the grade of some parameters. They received the voices and the protocol in the same way as the first evaluators.

The results are presented descriptively.

The intraclass correlation coefficient (ICC) was calculated to assess the agreement between the three judges for the auditory-perceptual and spectrographic vocal evaluation variables before and after the intervention, using the fixed effect model to estimate the agreement measure and the mean unit between evaluators. The coefficient varies between 0 and 1, with the closest to 1 indicating agreement and the closest to 0 indicating non-agreement. In the GRBASI, only the pre- and post-intervention A did not show agreement between the judges. In the spectrographic evaluation, some of the numerous variables evaluated by the SVAP[21] did not show agreement between the judges: regularity of the tracing in the high frequencies and in the spectrogram as a whole; B_{Fm} of F_1 and F_2; antiresonance immediately above F_1 and in the low frequencies; intensity of the color of the tracing of the low frequencies; presence of noise in the low frequencies and in the spectrogram as a whole;

replacement of nf_o by noise; definition, regularity and number of nf_o in low and medium frequencies and presence of sub-nf_o in high frequencies.

Regarding the characteristics of the participants (Table 1), the study included three men and one woman, who underwent CT and RT for an oropharyngeal tumor, with a dose between 44-70Gy and a completion time of 2-12 months. Regarding the results of salivary flow stimulation (Figure 1) at the beginning and end of treatment, it was observed that all patients presented an increase in salivary volume. A variable increase in salivary flow was identified, which went, on average, from 0.1 ml/min to 1.8 ml/min.

In the analysis of the GRBASI scale (Table 2), it was not possible to identify, through the judges' assessment, improvement or worsening after the intervention to increase salivary flow.

Table 3 shows the results of the acoustic analysis of the glottal source using the MDVPA program. There was a change in the f_o of all subjects after the intervention. Two subjects (S1, male, and S4, female) increased the f_o by an average of 22.372 Hz, and 2 subjects (S2 and S3, both male) decreased the f_o by an average of 9.093 Hz.

In the 4 subjects, there was an increase in RAP and PPQ measurements. In 3 of the 4 subjects, there was a decrease in fl_o and an increase in fhi, jita, jitt and SPI. However, a decrease in sPPQ, Shim, ShdB, APQ, NHR and VTI was observed.

In WBS (Table 4), in 3 of the 4 subjects, there was a worsening characterized by a reduction in the definition and regularity of F_1, a reduction in the regularity of the trace across the spectrum, and an increase in the bandwidth of F_4. There was an improvement characterized by a reduction in the antiresonance immediately above F_1, at low and high frequencies.

In the NBS (Table 5), in 3 of the 4 subjects, there was a worsening characterized by the reduction of the definition and regularity of the nf_o in the low and medium frequencies and in the entire spectrogram and the reduction of the number of nf_o in the medium frequencies and in the entire spectrogram. There was an improvement characterized by the reduction of the presence of noise in all aspects evaluated and a reduction of the presence of sub-harmonics in the high frequencies.

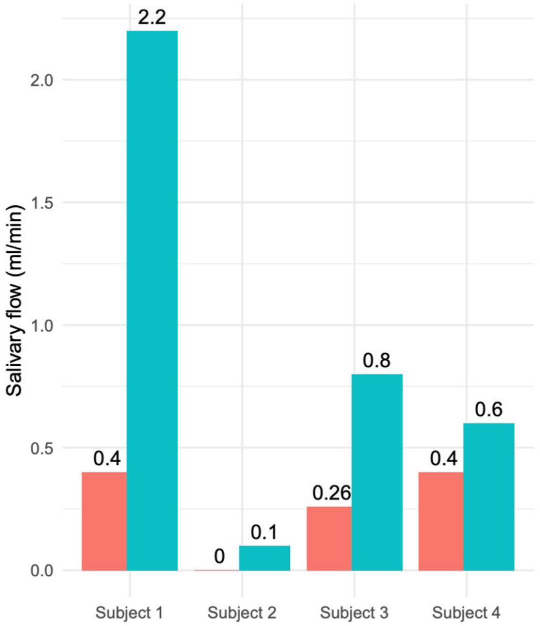

Figure 1. Salivary flow before and after intervention
Subtitle: ml/min – millimeters per minute

DISCUSSION

In this study, an increase in salivary flow was observed in all participants who underwent TENS intervention. This increase manifested itself as a subtle improvement in some of the vocal parameters, although still within normal limits (Table 1, Figure 1).

After TENS, saliva volume increased, but values were still below normal (1 to 3 ml/min), with a maximum of 2.2 ml/min[8]. A variable increase in salivary flow was observed in all patients, with an average increase of 0.66 ml/min. It is worth noting that when the salivary glands are included in the RT radiation field, the development of hyposalivation and/or xerostomia is common. The duration of this change varies from patient to patient and is subject to the radiation dose received, the radiation field used, and individual biological variations[6].

This condition occurs due to the sensitivity of the salivary glands to RT, which causes morphological and/or functional changes in their structure[5]. A possible influence on the observed results may be related to the RT dosage administered to patients. Xerostomia tends to manifest itself from the third or fourth week, when patients accumulate around 39Gy of radiation[5].

Regarding the time of completion of RT, studies show that some patients improved the degree of xerostomia, becoming milder over time. A cohort followed 80 post-RT patients for 37 months, in which 18.8% of patients improved xerostomia after approximately 18 months[28]. In the present study, subjects with lower salivary indices after TENS had a shorter post-radiotherapy time, at six and two months, and received 70Gy of RT.

Therefore, the damage to the salivary glands may have been extensive, making recovery more difficult. Studies indicate that more significant damage to the salivary glands occurs between 60 and 70Gy[28], data that confirm the results of this study.

However, although a relatively modest increase in salivary flow was observed, the findings are in agreement with the results of other studies[7,21] in which participants demonstrated an increase in salivary flow after the application of TENS, reporting notable improvements in quality of life, especially in the areas of speech, voice, chewing, and sleep.

Regarding the auditory-perceptual vocal analysis (Table 2), the results were inconsistent and heterogeneous, apparently diverging from the findings of a systematic review (SR) that covered 20 studies[29]. In the SR, the GRBASI scale revealed statistical significance in the intervention group, suggesting that reduced hydration conditions led to a decline in auditory-perceptual vocal quality.

The results of the acoustic vocal analysis of the glottal source revealed changes in the f_o of all participants after the intervention. In this study, it was observed that two participants, S1 (male) and S4 (female), increased the f_o by an average of 22.372 Hz, while two other participants, S2 and S3 (both male) decreased the f_o by an average of 9.093 Hz (Table 3). It is important to note that, despite this variation, all f_o values remained within the range considered normal for Brazilian speakers, which covers 80 to 150 Hz for men and 150 to 250 Hz for women[30].

These findings are in partial agreement with a previously conducted study[7], which evaluated f_o at baseline and after six

Table 1. Participant characteristics and salivary flow

Subjects	Gender	Age	Education	Tumor site	Surgery	RT dose (Gy)	RT method	CT	Time completed (months)	Salivary flow pre and post-intervention		
										Start (ml/min)	Final (ml/min)	Difference (ml/min)
Subject 1	M	67	Elementary Education	oropharynx	Yes	60	2D	Yes	12	0,4	2,2	1,8
Subject 2	M	61	Elementary Education	oropharynx	No	70	2D	Yes	6	0	0,1	0,1
Subject 3	M	48	Incomplete high school	oropharynx	No	44	2D	Yes	7	0,26	0,8	0,54
Subject 4	F	57	Completed higher education	oropharynx	Yes	70	2D	Yes	2	0,4	0,6	0,2

Subtitle: M=male; F= female; RT= radiotherapy; 2D = conventional radiotherapy; Gy=Grays; CT= chemotherapy; ml = milliliter; min = minute

Table 2. Auditory-perceptual vocal analysis

Subjects	Moment	G	R	B	A	S	I
Subject 1	Pre	2	1	0	0	0	2
	Post	2	1	0	0	0	1
Subject 2	Pre	2	2	1	1	0	2
	Post	2	1	1	2	0	1
Subject 3	Pre	0	0	0	0	0	0
	Post	1	0	0	0	1	1
Subject 4	Pre	1	1	1	0	0	0
	Post	1	1	0	0	0	1

Subtitle: G= Grade; R= Roughness; B=Breathiness; A= Astheny; S= Strain; I= Instability

Table 3. Acoustic vocal analysis of glottal source (Multi-Dimensional Voice Program Advanced)

Variables	MALE						FEMALE	
	S1		S2		S3		S4	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
f_o (Hz)	111,021	135,66	119,92	110,203	99,566	91,1	173,522	193,62
fhi (Hz)	122,423	140,53	124,28	115,352	103,29	121,81	290,427	486,25
flo (Hz)	96,073	129,18	116,03	106,151	96,457	87,898	97,216	67,764
STD (Hz)	6,729	2,27	1,463	1,485	1,195	1,889	61,446	52,923
Jita (us)	43,647	35,275	60,401	87,165	54,04	64,903	283,45	410,43
Jitt (%)	0,483	0,478	0,724	0,96	0,538	0,591	4,441	7,635
RAP (%)	0,279	0,28	0,403	0,565	0,262	0,282	2,692	4,503
PPQ (%)	0,272	0,284	0,46	0,557	0,299	0,345	2,853	4,996
sPPQ (%)	0,733	0,506	0,632	0,913	0,812	0,805	7,045	5,102
vf_o (%)	6,061	1,673	1,22	1,348	1,2	2,074	35,411	27,333
ShdB (dB)	0,589	0,334	0,731	0,7	0,456	0,546	1,835	1,131
Shim (%)	6,63	3,818	8,257	7,989	5,21	6,046	19,814	11,604
APQ (%)	5,548	3,706	6,697	5,726	4,431	4,943	14,063	7,995
sAPQ (%)	8,296	6,256	7,352	7,605	7,053	12,578	16,977	11,736
vAm (%)	25,551	12,444	11,025	11,495	16,829	22,545	30,724	23,574
NHR (%)	0,152	0,129	0,171	0,152	0,131	0,159	0,338	0,297
VTI	0,073	0,035	0,056	0,052	0,041	0,046	0,074	0,062
SPI	11,142	14,498	11,355	17,072	13,667	12,214	3,929	19,333
DVB (%)	0	0	0	0	0	0	8,42	41,008
DSH (%)	0	0	0	0	0	0	5,882	46,825
DUV (%)	0	0	0,826	0,826	0	1,653	61,364	4,545
NVB (%)	0	0	0	0	0	0	2	4
NSH (%)	0	0	0	0	0	0	3	59
NUV (%)	0	0	1	1	0	2	81	6

Subtitle: Pre and Post = before and after intervention with electrostimulation; S = subject; % = percentage; fo = fundamental frequency (Hz); fhi = maximum fo (Hz); flo = minimum fo (Hz); STD = standard deviation of fo (Hz); Jita = absolute jitter (us); Jitt = percentage or relative jitter (%); RAP = relative mean of pitch disturbance (%); PPQ = fo disturbance quotient (%); sPPQ = smoothed fo disturbance quotient (%); vfo = fo variation (%); ShdB = absolute or decibel shimmer (dB); Shim = percentage or relative shimmer (%); APQ = amplitude disturbance quotient (%); sAPQ = smoothed amplitude disturbance quotient (%); vAm = amplitude variation (%); NHR = noise-to-harmonic ratio (%); VTI = vocal turbulence index; SPI = smooth phonation index; DVB = degree of vocal breaks (%); DSH = degree of subharmonic components (%); DUV = degree of unvoiced segments (%); NVB = number of vocal breaks (%); NSH = number of subharmonic segments (%); NUV = number of unvoiced segments (%); dB = decibel

weeks of chemoradiotherapy treatment and observed a decrease in f_o in ten patients after RT for non-laryngeal cancer (five men and five women), together with an increase in f_o in four patients (two men and two women).

In the current study, the participants did not present any conditions at the time of the laryngeal examination performed at the beginning of the speech therapy intervention to stimulate salivary flow. However, according to other authors[7], the reduction in f_o was associated with an increase in the effective mass of the vocal folds due to edema in the laryngeal region. While the increase in f_o was attributed to the presence of pseudomembrane induced by mucositis, causing changes in the vibration of the vocal folds.

The increase in f_o observed in subjects 1 and 4, despite the increase in saliva volume, contrasts with the results of a randomized, placebo-controlled clinical trial. This study involved the stimulation of salivary flow by means of pilocarpine mouthwash and evaluated the interference of saliva on laryngeal hydration/lubrication and voice quality in healthy individuals. In this study, the subjects also experienced an increase in salivary production, but there was a reduction in f_o. The authors suggest that, with the increase in lubrication, even if minimal, there was

Table 4. Broadband Spectrography

Parameters	Intensity	S1		S2		S3		S4	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
F trace color intensity (%)	F1	84	70	72	85	53	52	33	62
	F2	84	51	54	72	36	36	30	40
	F3	48	42	47	41	19	25	21	25
	F4	37	25	41	33	14	19	17	25
Trace color intensity (%)	LF	85	66	68	75	46	43	41	52
	MF	65	49	42	49	30	25	25	36
	HF	46	33	46	48	17	17	19	28
	Spectrogram as a whole	73	58	60	62	40	36	36	45
Definition and regularity of F (%)	F1	94	79	81	80	45	40	31	50
	F2	85	52	64	73	38	35	26	41
	F3	63	49	44	43	17	17	18	31
	F4	46	28	48	40	13	14	15	26
Regularity of the line (%)	From vertical striations at low frequencies	58	50	59	66	38	40	30	28
	From vertical striations in the medium frequencies	48	40	43	45	35	34	28	28
	From vertical striations at high frequencies	39	28	46	35	29	30	24	24
	In the vocal spectrogram as a whole	53	39	46	39	39	39	29	24
Bandwidth (%)	F1	51	57	48	50	55	51	38	51
	F2	48	43	43	46	46	39	35	39
	F3	37	40	36	36	16	16	26	38
	F4	33	20	45	49	14	19	26	37
Antiresonance/ damping/ damping/intensity decay/negative resonance (%)	Immediately above F1	16	3	0	2	3	1	6	0,60
	LF	5	3	0	3	3	1	9	5
	MF	3	10	0	8	44	30	10	7
	HF	10	4	0	4	47	32	21	2
	Spectrogram as a whole	9	10	0	9	39	30	21	9

Subtitle: S = subject; % = percentage; Pre and Post = before and after stimulation with Transcutaneous Electrical Nerve Stimulation; F1 = first formant; F2 = second formant; F3 = third formant; F4 = fourth formant; LF = low frequency; MF = medium frequency; HF = high frequencies

Table 5. Narrowband Spectrography

Parameters	Intensity	S1		S2		S3		S4	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Trace color intensity (%)	LF	79	71	67	67	60	56	57	59
	MF	62	65	37	57	49	24	41	40
	HF	36	34	50	51	19	9	12	34
	Spectrogram as a whole	58	62	53	52	41	33	38	49
Presence of noise (%)	LF	40	28	30	31	31	22	46	22
	MF	40	47	38	37	26	23	44	36
	HF	40	47	38	37	26	23	44	36
	Spectrogram as a whole	41	44	43	41	34	30	49	35
Replacement of harmonics by noise (%)	LF	34	30	36	34	5	5	8	16
	MF	32	45	35	25	13	24	24	23
	HF	43	51	30	25	27	31	20	21
	Spectrogram as a whole	37	37	37	28	19	30	28	29
Definition and regularity of harmonics (%)	LF	52	51	56	55	45	42	38	58
	MF	51	36	44	37	40	23	31	33
	HF	34	30	36	34	5	5	8	16
	Spectrogram as a whole	45	41	45	35	28	25	29	39
Number of harmonics (%)	LF	46	51	60	57	60	55	41	61
	MF	49	38	46	39	36	26	25	34
	HF	26	32	45	40	5	5	9	20
	Spectrogram as a whole	45	42	51	46	34	35	25	34
Presence of subharmonics (%)	LF	16	16	16	20	11	12	25	10
	MF	16	21	24	18	11	11	26	26
	HF	19	14	16	13	11	7	12	18
	Spectrogram as a whole	18	22	19	20	11	6	26	18

Subtitle: S = subject; % = percentage; Pre and Post = before and after stimulation with Transcutaneous Electrical Nerve Stimulation; LF = low frequency; MF = medium frequency; HF = high frequencies laryngeal penetration that influenced the speed of the vocal fold opening and closing cycles[6].

The subjects in the present study presented hyposalivation and increased viscosity of residual saliva, which made it difficult to lubricate the vocal tract. Although the analysis of the saliva produced after the intervention was not the object of the study, it can be inferred that the possible reduction in salivary viscosity contributed to the considerable increase in f_o in subjects 1 and 4. This hypothesis is based on the premise that less viscous saliva would facilitate the vibratory movement of the vocal folds, allowing them to vibrate more frequently.

Regarding participants 2 and 3, a reduction in f_o was observed, despite a slight increase in salivary flow. The possible influence of the quality of the mucus produced and greater adhesion to the vocal folds may reduce the number of vibration cycles, justifying this reduction in f_o. However, it is important to emphasize that the analysis of the viscosity and adhesive properties of the mucus was not performed in this study.

Furthermore, regarding f_o, an increase in fhi was observed in three participants and a decrease in flo in three of the four participants (Table 3). These changes suggest an increase in f_o fluctuation during the sustained emission, indicating instability. This variation can be explained by the lack of vocal training of the participants[21], but it can also be a reflection of the slight increase in salivation/lubrication obtained in the experiment.

Regarding the f_o disturbance measures, the four participants showed an increase in the RAP and PPQ parameters; Three of the four subjects showed an increase in jita and jitt and a decrease in sPPQ at the end of the intervention (Table 3). It is important to note that high Jitter values have been correlated with the presence of noise in the voice or hoarseness, as observed by other authors[5]. The result obtained suggests that, together with vocal instability, there was an increase in the f_o disturbance in vocal emissions. This could be related to the increase in post-intervention lubrication, which may have caused greater disturbance in the movement of the vocal folds.

Additionally, individuals 1, 2 and 4 showed decreased amplitude disturbance measures, including ShdB, Shim and APQ. Shimmer is often associated with noise and periodicity in vocal production and tends to be higher in cases of vocal breathiness[24].

Similarly, these same individuals exhibited reductions in noise measures, including NHR and VTI. These noise measures assess the presence of noise in various bands of the vocal spectrum or across the entire spectrum, and are often associated with deviated voices[24]. Such improvements in amplitude disturbance and noise measures may indicate improved quality of vocal fold closure during phonation, reducing air escape and noise. This result may be related to the slight increase in salivation/lubrication obtained with the intervention.

In the WBS (Table 4), in three of the four subjects, there was a worsening characterized by a reduction in the definition and regularity of F_1, a reduction in the regularity of the trace across the spectrum, and an increase in the bandwidth of F_4. There was an improvement characterized by a reduction in the antiresonance immediately above F_1, at low and high frequencies.

In the NBS (Table 5), in three of the four subjects, there was a worsening characterized by a reduction in the definition and regularity of the nf_o in the low and medium frequencies and in the entire spectrogram, and a reduction in the number of nf_o in the medium frequencies and in the entire spectrogram. There was an improvement characterized by a reduction in the presence of noise in all aspects evaluated and a reduction in the presence of subharmonics in the high frequencies. These results confirm those obtained through the acoustic vocal analysis of glottal source in which an increase in the measures of frequency disturbance and instability and a reduction in noise and air escape were observed.

Interestingly, despite these objectively observed modifications in acoustic vocal measurements, no significant changes were perceived in the auditory-perceptual analysis, suggesting that discrete vocal modifications may not be sufficiently perceived by the human ear and that acoustic analysis appears to be more sensitive.

The discrepancy between the results of the auditory-perceptual vocal evaluation and the acoustic vocal evaluation, in agreement with a previous study[29], may have originated due to the extremely subtle vocal changes, almost imperceptible to the human ear. Furthermore, the discrepant results between the auditory-perceptual and acoustic vocal evaluations, as well as the simultaneous improvements and worsening found in the acoustic evaluation, can be attributed to the small number of subjects, the variability in the response to treatment among patients and the varied post-RT time among subjects, which could have favored greater vocal recovery in those with a longer post-RT time.

Despite these possible intervening and limiting variables, it is inferred that the increased amount of saliva produced may have contributed to the humidification of the vocal tract and interfered with the vibration cycles of the vocal folds and the characteristics of the glottic signal, although not conclusively. This observation is supported by a previous study[4] that, when using a radioactive contrast, demonstrated the presence of saliva not only in the oral cavity and oropharynx, but also in the vallecula and laryngopharynx, projecting up to the laryngeal vestibule. This occurred even in the absence of complaints of discomfort, coughing or adverse reactions to radioactive saliva in the larynx, which reinforces the idea that hyposalivation impacts the functioning of the larynx.

FINAL COMMENTS

TENS was shown to induce a variable increase in salivary flow with some acoustic vocal improvements, while the auditory-perceptual vocal evaluation revealed no differences between the pre- and post-intervention moments. In the acoustic analysis of the glottal source, an increase in f_o was observed, suggesting a higher pitch of the voice, a decrease in flo and an increase in f_o and SPI disturbance measures, signaling greater aperiodicity and loss of energy in high f_o of the spectrum. There was also a decrease in amplitude disturbance measures, NHR and VTI, indicating less transglottic air escape and less noise during emission.

In the acoustic spectrographic evaluation of the voice, worsening was recorded with reduction in the definition and regularity of F_o and nf_o and in the regularity of the tracing, suggesting the presence of instability. There was an improvement characterized by the reduction of antiresonance, the presence of noise and subharmonics.

The case series presented here indicates that TENS may have the potential to increase salivary flow in patients with RT-induced hyposalivation. However, to fully understand the late effects and changes in vocal parameters resulting from this increase, more extensive follow-up and analysis of a larger sample are necessary. It is worth noting that the results reflected changes worthy of further investigation regarding the role of saliva in vocal quality. It is important to mention that some of the limitations of this study were: addition of dimethicone to the sample, which could interfere with the composition of saliva or vocal results, even with the subtraction of the volume corresponding to the dimethicone drops to control for this interference; variation in post-radiotherapy time among patients; and small number of participants. It is recommended that further investigations be carried out in a larger sample, with greater standardization of intervening variables and in the long term.

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