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Correlation between cervical auscultation and electromyography in the pharyngeal phase of swallowing

Correlação entre ausculta cervical e eletromiografia de superfície na fase faríngea da deglutição

Correlación entre auscultación cervical y electromiografía de superficie en la fase faríngea de la deglución

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Abstract

Objective: Correlate the acoustic data of cervical auscultation to the electrical activity of the muscles involved in the pharyngeal phase of swallowing. **Methods:** This is an observational, cross-sectional study involving a quantitative approach and was approved on January by CEP/UFSCPA (number 1.389.050). All participants of the study signed an informed consent form. The pharyngeal phase of swallowing was assessed by employing auscultation and surface electromyography. Individuals ingested 90 ml of water. The auscultation data were transferred to DeglutiSom® software, the duration and amplitude of electromyographic activity was measured during swallowing using a Miotec® surface electromyography device. The level of significance adopted was 5%. **Results:** Fifty-seven women participated in this study. The average age was 23.4 years on average. It must be highlighted that the greater the average peak frequency of auscultation, lower was the average peak of the suprahyoid muscle and the greater the intensity, the greater was the peak, as well as the average of the suprahyoid peaks. It was possible to demonstrate that the peak of suprahyoid muscle activity was significantly higher than the peak of infra hyoid muscle activity for swallowing 90 ml of water. **Conclusion:** The acoustic swallowing parameters in healthy individuals are correlated with the electrical activity of muscles involved in the pharyngeal phase of swallowing.

Keywords: Deglutition; Deglutition Disorders; Auscultation; Electromyography; Electrophysiology

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Resumo

Objetivo: Correlacionar os dados acústicos da ausculta cervical com a atividade elétrica dos músculos envolvidos na fase faríngea da deglutição. **Métodos:** Trata-se de um estudo observacional, transversal, de abordagem quantitativa, aprovado em janeiro pelo CEP/UFSCPA (número 1.389.050). Todos os participantes do estudo assinaram o termo de consentimento livre e esclarecido. A fase faríngea da deglutição foi avaliada por meio de ausculta cervical e eletromiografia de superfície. Os indivíduos ingeriram 90 ml de água. Os dados da ausculta foram transferidos para o DeglutiSom® software, a duração e amplitude da atividade eletromiográfica foram mensuradas durante a deglutição com aparelho de eletromiografia de superfície Miotec®. O nível de significância adotado foi de 5%. **Resultados:** Cinquenta e sete mulheres participaram deste estudo. A média de idade foi de 23,4 anos. Ressalta-se que quanto maior a frequência média do pico da ausculta, menor é a média do pico do músculo supra-hióideo e quanto maior a intensidade, maior é o pico, assim como a média dos picos supra-hióideos. Foi possível demonstrar que o pico de atividade do músculo supra-hióideo foi significativamente maior do que o pico de atividade do músculo infra-hióideo para a deglutição de 90 ml de água. **Conclusão:** Os parâmetros acústicos da deglutição em indivíduos saudáveis estão correlacionados com a atividade elétrica dos músculos envolvidos na fase faríngea da deglutição.

Palavras-chave: Deglutição; Transtornos de Deglutição; Auscultação; Eletromiografia; Eletrofisiologia

Resumen

Objetivo: Correlacionar los datos acústicos de la auscultación cervical con la actividad eléctrica de los músculos involucrados en la fase faríngea de la deglución. **Métodos:** Se trata de un estudio observacional, transversal, de abordaje cuantitativo y aprobado en enero por CEP/UFSCPA (número 1.389.050). Todos los participantes del estudio firmaron un formulario de consentimiento informado. La fase faríngea de la deglución se evaluó mediante auscultación y electromiografía de superficie. Los individuos ingirieron 90 ml de agua. Los datos de auscultación fueron cargados em el software DeglutiSom®**,** la duración y la amplitud de la actividad electromiográfica se midió durante la deglución utilizando un dispositivo de electromiografía de superficie Miotec®. El nivel de significancia adoptado fue del 5%. **Resultados**: Cincuenta y siete mujeres participaron en este estudio. La edad promedio fue 23,4 años. Cabe destacar que a mayor frecuencia de pico promedio de auscultación, menor fue el pico promedio del músculo suprahioideo y a mayor intensidad, mayor fue el pico, así como el promedio de los picos suprahioideos. Fue posible demostrar que el pico de actividad del músculo suprahioideo era significativamente más alto que el pico de actividad del músculo infrahioideo para tragar 90 ml de agua. **Conclusión**: Los parámetros de deglución acústica en individuos sanos se correlacionan con la actividad eléctrica de los músculos involucrados en la fase faríngea de la deglución.

Palabras clave: Deglución; Trastornos de la deglución; Auscultación; Electromiografía; Electrofisiología.

Introduction

Normal swallowing is characterized by the transportation of food bolus or saliva from the mouth to the stomach, protecting the airway from aspiration. [1-3] The swallowing process is a neuromuscular activity and is divided into the following phases: anticipatory; oral: oral preparatory and oral transit; pharyngeal and esophageal. [3]

Swallowing sounds are the result of structural and muscular movements that drive the bolus through the esophagus, into the stomach. These movements also prevent the food bolus from entering the airway. [4]

Cervical auscultation is a complementary method of clinical evaluation of dysphagia that enables one to listen to these swallowing sounds. Sounds to be auscultated are picked up by amplification instruments and, subsequently, they may be transferred to computerized programs, which then carry out an acoustic sound analysis. This provides quantitative and visual data on the amplitude, duration, and sound frequency, besides suggesting normalcy or impairment in swallowing.[4-6] During clinical evaluations, differences in cervical auscultation sounds of individuals without complaints of difficulty while swallowing were found. These may be influenced by numerous factors such as age, consistency, volume offered, and anatomical inter-subject differences.[7-8]

Some studies state that the duration of the first swallowing interval is 108 ± 44 ms while that of the second interval is 236 ± 139 ms, studies describe the sounds during swallowing on digital cervical auscultation as the beginning of swallowing, which produces a signal duration of 0.05 s, followed by a silent interval of 0.1 s–0.15 s. In contrast, the second sound may be heard between 0.15 s–0.2 s. The means of swallowing sounds in normal individuals are at a frequency of 0–8 kHz, with an energy level of 0–2 kHz, duration 0.25 s–3 s, and intensity range of 4 dB–41 dB. [5-8]

Surface electromyography (sEMG) is a method for assessing supplementary muscle groups that may serve as a basis for comparing the physiopathological condition of the muscles involved. This may confirm the activation of certain muscle groups to execute specific tasks. There is no consensus on the difference in time and amplitude of muscle activity between sexes during an electromyography evaluation.[9,10,11]

In studies conducted with adults having no history of dysphagia or medical problems that might affect swallowing, during swallowing the amplitude of the suprahyoid muscle, varies from 23μV to 40.76 μV. 17 .The duration of muscle activity of the suprahyoid muscle during swallowing varies from 1.0 s to 2.05 s. The volume and consistency of food modify the values. [12] There is no consensus on the difference in duration and amplitude of muscle activity between sexes in electromyography evaluation. [10,11]

Several studies have reported that one of the most important acoustic signals of the swallowing sound corresponds to the movement of the supra- and infrahyoid musculature, in addition to the displacement of the larynx, and through the cricopharyngeal muscle, therefore, the acoustic signs of swallowing may be correlated with the electromyography surface. [5,7,8]

It is necessary to study the correlation between sEMG and cervical auscultation, as these data give an indication of the biomechanics of deglutition, thus helping in clinical speech therapy. Therefore, this study aimed to correlate acoustic data from cervical auscultation with muscle electrical activity in the pharyngeal phase of swallowing without disorders.

Methods

Ethical procedures

This was an observational, cross-sectional, quantitative study that was approved on 01/15/16 by the Research Ethics Committee of the Federal University of Health Sciences of Porto Alegre (UFCSPA; number 1.389.050). All the participants of the study signed an informed consent form.

Sample

The sample consisted of 57 subjects, and according to the complaints, women with swallowing disorders were included; who were in the age group of 18 to 59 years and 11 months, and belonging to the UFCSPA were included. The exclusion criteria were as follows: adults with neurologic and respiratory disorders, including the head and neck, or sequelae thereof; those who had undergone a tracheotomy; elderly individuals and three male participants due to non-parity of data. Data collection was carried out in March 2017.

Procedure

Data collection was done at the UFCSPA. Initially, an interview was conducted where a questionnaire with open- and close-ended questions was filled, data on age and no difficulty in swallowing. Before fixing the electrodes, electrical impedance at the sites of electrode contact was reduced because target areas had been lightly scrubbed with alcohol 70%. The ground electrode was fixed on a bone surface (clavicle).[10-12]

To perform the recording, a surface electromyography device was used.-sEMG model EMG 400c, with four channels the Miotec®. Electrical activity was registered using disposable, self-adhesive electrodes. The signal picked up by the electrodes was filtered with a band pass filter of 20 Hz–500 Hz.

The root mean square measurements of duration and amplitude of the electromyography activity during swallowing were obtained using the Miotec® sEMG device functions.

The electrodes were fixed on the skin at the submental region, in a position anterior to the neck on both sides, which refers to the suprahyoid muscles group. The electrodes were placed parallel to the anterior belly of the digastric, mylohyoid, and geniohyoid muscles and were horizontally separated from each other (center to center) by 2 cm. Two additional electrodes were fixed in the anterior region of the neck, lateral to the thyroid cartilage of the larynx, which refers to the infrahyoid muscle, horizontally separated from each other (center to center) by 2 cm. The electrodes were cut so as not to interfere with laryngeal movement.

These muscles were selected because they are superficial and are involved in the pharyngeal phase of swallowing. The exact electrode position for each of the previously known muscles was clarified after anatomical correlation.[10-12]

Subsequently, participants were informed of the procedures to be performed, which involved sitting upright with feet parallel to the floor; positioning the head medially to the neck; and swallowing 90 ml of liquid (water) from a plastic cup, without interruption to record cervical auscultation and surface electromyography. The volume of water offered was based on that of a previous study.[13]

Cervical auscultation was carried out using a Littmann® Model 3100 electronic stethoscope, which attenuates a noisy environment by approximately 85% (-12 dB) without eliminating the important physiological sounds. The stethoscope was positioned below the region of the cricoid cartilage [4,9] , so that the signal to be captured would not interfere with the electromyography signal.

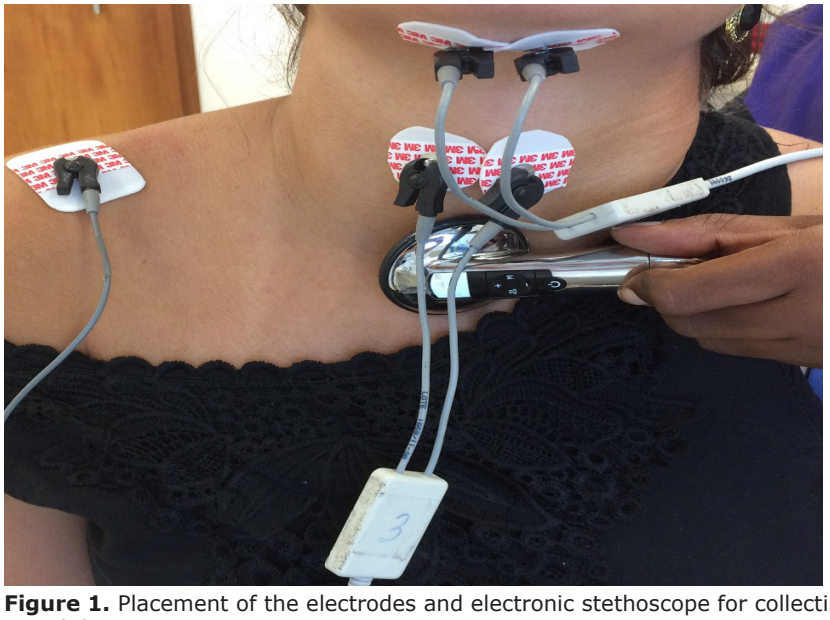

Figure 1. Placement of the electrodes and electronic stethoscope for collecting electromyography signal data.

The signals/sounds collected by the electronic stethoscope were transmitted to a computer via Bluetooth and transferred to software, Degluti-Som®, which was developed for recording the acoustic signals of swallowing.

Statistical analysis

Quantitative variables are expressed as means and standard deviation. Categorical variables are expressed as absolute and relative frequencies.

Student's t-test was used to compare means. The correlation between variables was evaluated using Pearson's correlation coefficient.

The level of significance adopted was 5% ($p < 0.05$) and analyses were performed using SPSS, version 21.0.

Results

During the swallowing of the 90 ml of liquid (water), the average peak frequency and swallowing intensity captured by cervical auscultation were 692 Hz and 42 dB, respectively. The peak and the mean peak of the suprahyoid muscle sEMG of the suprahyoid muscle were 124.2 **µ**V and 37.4 **µ**V. These data revealed that the greater the mean frequency, the lower the mean peak of the suprahyoid muscle; and the greater the intensity of swallowing, the greater the peak and mean peak of the suprahyoid muscle. The Table 1 shows the correlation of acoustic data from cervical auscultation (intensity and frequency) with the electrical activity of the suprahyoid and infrahyoid muscles, demonstrating the interference of muscle electrical activity in frequency and intensity.

Table 1. Correlation between electrical activity, frequency, and intensity

Variables	Average peak frequency	p	Intensity	p
	Pearson correlation coefficient		Pearson correlation coefficient	
Suprahyoid peak (µV)	-0.111	0.412	0.273	0.040
Mean suprahyoid (µV)	-0.252	0.049	0.264	0.047
Infrahyoid peak (µV)	0.016	0.904	0.183	0.172
Mean infrahyoid (µV)	-0.004	0.979	0.126	0.346

µV: microvolts

In this study, women presented a time of 1.9 s for each swallow. When correlating the duration of swallowing to electrical activity, no significant difference was found.

The Table 2 shows the correlation between the peak and the average suprahyoid and infrahyoid muscle activity. There was a significant difference between the peaks and the means of the suprahyoid and infrahyoid muscle activity ($p < 0.001$), which suggests that the peak of the suprahyoid muscle activity was significantly higher than that of the infrahyoid muscle activity while the 90 ml liquid was swallowed. However, there was no significant correlation between the suprahyoid and infrahyoid peaks ($r = 0.032$; $p = 0.808$) or between the means of both muscle groups ($r = 0.134$; $p = 0.308$).

Table 2. Surface electromyography data for swallowing

Variables	n = 57
Suprahyoid peak (µV) – average ± SD	124.2 ± 54.0
Suprahyoid mean (µV) – mean ± SD	37.4 ± 18.1
Infrahyoid peak (µV) – mean ± SD	44.9 ± 26.5
Infrahyoid mean (µV) – mean ± SD	17.8 ± 9.2

µV: microvolts; SD: standard deviation.

Discussion

The electromyographic characteristics of the muscles related to the pharyngeal phase of swallowing are widely described in the literature [10,13-15], but the association with acoustic data from cervical auscultation has not yet been described.

The sample characteristics of this study show the participation of the female population in research, similar to the collection of electromyography data [16-18] and acoustic data regarding swallowing. [4,19,20]

As for the mean frequency of peak swallowing of 90 ml of liquid, we found an association with the mean amplitude of the suprahyoid muscle. This can be explained by the function of elevating the larynx in the cervical region performed by these muscles (anterior belly of the digastric, mylohyoid and geniohyoid), interfering in the variation of the acoustic frequency, a direct consequence of this movement. [21-23] In this analysis, the greater the intensity of auscultation, the greater the peak and the mean peak of activity of the suprahyoid muscle, which is in agreement with the published values regarding the electrical activity of swallowing, which for this muscle has an average of 32.2 μV. [15] This suggests that the basic mechanism of protection of the lower airways during swallowing consists of, among other events, anterior laryngeal displacement and elevation. This demonstrates that the greater the muscular displacement during swallowing, the greater the muscular activity for this function and consequently the greater the protection of the airway of the individual.[22,24]

The frequency range found for swallowing in this study corroborates previously published data regarding gender.[8,23-26] This could be justified by the higher position of the larynx in women, generating a variation in the peak frequency, as it is related to the magnitude of contraction of the swallowing tube. [23]

A recently published study showed that the initial time of swallowing 10 ml of liquid was 1.6 s. [24] In that study, the time for each swallow was 2.1s for men and1.9 s for women. This difference may be explained by the amount of liquid offered to individuals although no correlation between the time of swallowing and electrical activity was found.[12,27,28]

With regard to the statistical difference between the peak and average suprahyoid and infrahyoid muscle activity, it has been found in the literature that there is a difference in the activation of the suprahyoid muscle during swallowing.. [16,17] Studies indicate that activation of the infrahyoid muscle occurs simultaneously with the activation of the suprahyoid muscle. [11] Studies reveal that the peaks of muscle activity may vary according to the head position at the time of swallowing. 38 Furthermore, sEMG swallowing records vary substantially among individuals. This suggests that individuals may have unique activation characteristics for each muscle group during normal swallowing..[29,30]

The correlation between the sounds and muscular activity in the pharyngeal phase of swallowing in healthy people could be regarded as a tool for the identification of the sound components and the swallowing physiology.

Future studies on normal swallowing with a greater number of participants, of both genders, with different consistencies, viscosities and volumes should be applied for possible comparisons with clinical data from dysphagic patients.

Conclusion

In conclusion, the acoustic swallowing parameters in healthy individuals are correlated with the electrical activity of muscles involved in the pharyngeal phase of swallowing.

We found that the higher the mean peak frequency, the lower the peak of the suprahyoid muscles, and the higher the intensity of swallowing, the higher the peak and the average peak of the suprahyoid muscles. It was possible to show that the peak of muscular activity of the supra-hyoid region was significantly greater than the peak of muscular activity of the infrahyoid region during uninterrupted swallowing of 90 ml of water.

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