REVISTA CEFAC
SPEECH, LANGUAGE, HEARING SCIENCES AND EDUCATION JOURNAL
Rev. CEFAC. 2017 Maio-Jun; 19(3):350-359 doi: 10.1590/1982-0216201719312316

Original articles

Acoustic analysis of swallowing time through Doppler Sonar

Análise acústica do tempo de deglutição através do Sonar Doppler

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Conflict of interest: non-existent

Received on: September 11, 2016
Accepted on: March 31, 2017

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ABSTRACT

Objective: to compare the acoustic oropharyngeal swallowing time parameter in adult and elderly subjects, in different consistencies and volumes, using Doppler Sonar.

Methods: the study was conducted in two stages. Firstly, the Screening Protocol of Swallowing Risk was applied. In the second stage, the individuals were submitted to a swallowing assessment with Doppler Sonar. The subjects received the following food consistencies during the assessment: dry swallowing (saliva), liquid, nectar, honey and pudding, in the volumes of 5 ml, 10 ml and free swallowing. The acoustic parameter analyzed in this study was Acoustic Swallowing Time (T).

Results: objective and measurable outcomes were obtained; the difference in swallowing time between the adult and elderly subjects in relation to the consistency and the volume was mostly significant.

Conclusion: a change in swallowing time was observed both in relation to the consistency and the volume of the food bolus when the elderly and adult subjects were compared.

Keywords: Swallowing; Time; Acoustic

RESUMO

Objetivo: comparar o parâmetro acústico de tempo da deglutição orofaríngea nos adultos e idosos, nas diferentes consistências e volumes, através do Sonar Doppler.

Métodos: a pesquisa foi realizada em duas etapas. Na primeira foi aplicado o Protocolo de Triagem de Risco para Deglutição. Na segunda os indivíduos foram submetidos à avaliação da deglutição com o Sonar Doppler. Os indivíduos receberam as seguintes consistências alimentares durante a avaliação - deglutição seca (saliva), líquida, néctar, mel e pudim, nos volumes de 5 ml, 10 ml e deglutição livre. O parâmetro acústico analisado neste estudo foi o Tempo acústico da deglutição (T).

Resultados: dados objetivos e mensuráveis foram obtidos; a diferença do tempo de deglutição entre adultos e idosos em relação à consistência e o volume foi, na maioria, significante.

Conclusão: verificou-se que há modificação do tempo da deglutição, tanto em relação à consistência quanto a volume do bolo alimentar, quando comparados idosos e adultos.

Descritores: Deglutição; Tempo; Acustica

INTRODUCTION

The World Health Organization (WHO) predicts that in the year 2025 the elderly population will exceed the underage cohort for the first time in the history of Brazil. The growth of the elderly population is a global trend requiring the promotion of health policies to maintain the quality of life of the elderly[1,2].

During the aging process, all functions and musculature of an individual are subjected to changes and adaptations. Swallowing is no exception. The clinical status of the individual can be affected not only by presbyphagia and swallowing disorders arising from aging, but also by dysphagia arising from neurological and/or structural diseases [3-5].

Aging itself is not the cause of oropharyngeal dysphagia, but studies have shown that the swallowing function in healthy elderly individuals is different when compared with the swallowing of younger people. Swallowing in individuals above 60 years of age, i.e., the elderly, is changed in its oral, pharyngeal and esophageal stages, contributing to the appearance of dysphagic symptoms, making the swallowing function in the elderly more vulnerable to disturbances caused by small changes in health. As such, this population is more susceptible to swallowing disorders[6].

Changes in the oral, pharyngeal and esophageal stages can be found in presbyphagia. In the early stages, there may be an increase in the duration of the transit of the food bolus due to the decreased sensitivity and muscle strength of the organs responsible for swallowing, and in the esophageal stage this can occur due to the higher frequency of non-propulsive contractions [6,7].

An assessment of the swallowing function can be performed with instruments in order to diagnose and monitor this disorder, with videofluoroscopy, nasofibroscopy and cervical auscultation being the most commonly used tools [8,9].

One of the methods with a still relative discrete number of publications, with little more than 10 years of research, is the assessment of swallowing with Doppler Sonar. This may become a promising test among the swallowing assessment methods, including for the elderly population, since it is a painless, non-invasive and low cost test that doesn't expose subjects to radiation[10-13].

The aforementioned method is based on the swallowing sounds, providing audible clues, which, in principle, could aid in obtaining a reliable classification as a screening system to identify patients at a higher risk of aspiration and laryngeal penetration [10-13].

The objective of this study is to compare the acoustic oropharyngeal swallowing time parameter of different consistencies and volumes for the adult and elderly age cohorts using Doppler Sonar.

METHODS

The study was conducted in two stages. In the first stage, the Swallowing Risk Screening Protocol[14] was applied, which contains questions related to dysphagia risk factors (Appendix 1). Volunteers with neurological diseases, structural changes to the head and neck, exposed to radiotherapy and/or chemotherapy and individuals with swallowing complaints, i.e., dysphagia risk factors, were excluded. Two groups were defined, group I (GI) was made up of healthy elderly individuals over 60 years of age, and group II (GII) was made up of healthy individuals aged between 18 and 59 years.

In the second stage, individuals from both groups were submitted to the oropharyngeal swallowing assessment with Doppler Sonar[13] following the assessment methodology used and described by Sória, Silva and Furkim (2015). The classification of the National Dysphagia Diet Guidelines (2002)[15] was used. The subjects then received the following food consistencies during the assessment - liquid, nectar, honey and pudding, using the volumes of 5 ml and 10 ml for free swallowing, adding dry swallowing (saliva) at the beginning of the assessment. Four swallows were requested for each consistency and volume.

The acquisition of the swallowing sounds with the Doppler Sonar was performed with the individual seated and with the neck unobstructed. The transducer was placed on the lateral region of the trachea, immediately below the cricoid cartilage, on the right side, and the transducer beam was positioned to form an angle of 30º to 60º [16].

The equipment used was the (portable) Ultrasonic Detector of the brand Martec, model DF-8014. The ultrasound frequency by Doppler effect was 2.5 MHz, with an output of 10 mW/cm2. The equipment was connected to a microcomputer. The Voxmetria software was used for the acoustic analysis of the sound signal captured by the sonar. The volume was adjusted to setting no. 3 for the acquisition of the sound signal with the continuous Doppler device. The analyzed intensity limits were 10 dB and 140 dB at the low and high end, respectively (Figure 1).

Figure 1. Doppler sonar coupled to a computer and the contact gel

The acoustic parameter under analysis in this study is the Acoustic Swallowing Time (T), defined by Santos and Macedo[10] as the interval between the swallowing apnea point, initial intensity (II), until the expiratory glottal release after swallowing, final Intensity (IF)[17], forming the total swallowing equation T:dA (dA - swallowing apnea)[17]. (Figure 2)

The statistical method used in this study was made up of the significance test in inferential statistics. The Student t test with an equal variance of two samples and a significance level of 0.05 was used to analyze the significance of the data obtained for the comparison of the acoustic swallowing time parameter between the elderly group and the adult group for each consistency and each volume. The elderly group (GI) and the adult group (GII) were cross-referenced in the statistical analysis, comparing the proposed parameter with the Anova method.

This study was approved by the Ethics Committee under number 00061/2008.

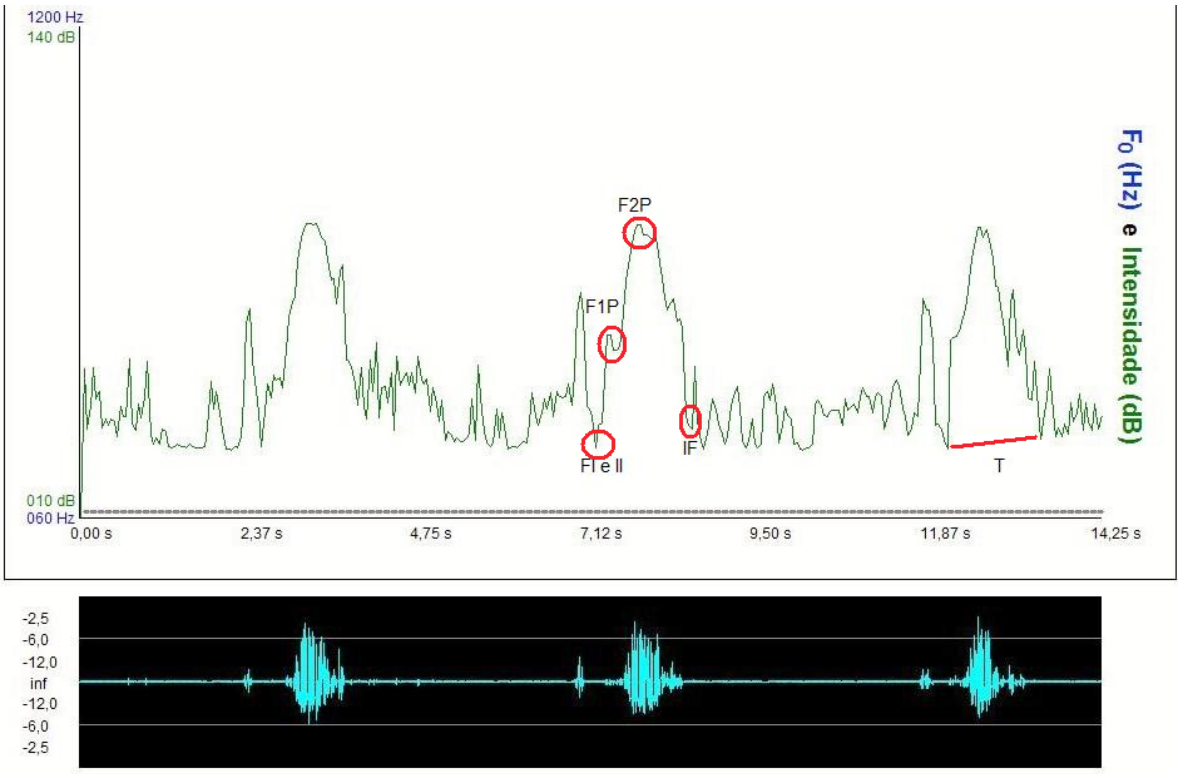

Figure 2. Acoustic parameters

RESULTS

189 individuals were evaluated, with 147 remaining for participation in the second stage of the study.

Group I (GI) was made up of 75 healthy elderly individuals with an average age of 71 years. Group II (GI) was made up of 72 healthy individuals with an average of 42 years.

Table 1 shows the data obtained in the swallowing time study for the adults and elderly individuals regarding the liquid, nectar, honey and pudding consistencies for the volumes of 5 and 10ml, free and saliva swallowing. A significant difference can be observed between the means ($p < 0.05$) in the comparison of swallowing time between the two groups, both regarding the different consistencies and volumes, except for nectar and honey in the volume of 5 ml. That is, in general, the swallowing time of the elderly was longer than that of adults for different consistencies and volumes.

Table 1. Comparison between the elderly group (GI) and the adult group (GII) regarding Time (T) saliva em inglês

CONSISTENCY	ADULTS (n=72)		ELDERLY (n=75)		p
	Mean	Standard Deviation	Mean	Standard Deviation	
Saliva	1.34	0.08	1.70	0.18	0.0000*
Free liquid	1.26	0.09	1.50	0.27	0.0000*
Liquid 5 ml	1.24	0.11	1.36	0.20	0.0000*
Liquid 10 ml	1.56	0.09	1.69	0.20	0.0000*
Free nectar	1.22	0.17	1.50	0.29	0.0000*
Nectar 5 ml	1.37	0.19	1.34	0.20	0.3161
Nectar 10 ml	1.53	0.27	1.66	0.24	0.0040*
Free Honey	1.82	0.07	1.54	0.25	0.0000*
Honey 5 ml	1.42	0.15	1.37	0.20	0.1133
Honey 10 ml	1.43	0.15	1.68	0.21	0.0000*
Free Pudding	1.57	0.12	1.47	0.28	0.0104*
Pudding 5 ml	1.30	0.18	1.37	0.20	0.0260*
Pudding 10 ml	1.37	0.18	1.57	0.23	0.0000*

(*) Significant differences at a significance level of 0.05
Student's t-test

The swallowing time for different consistencies for adults and the elderly considering the volume of 5 ml is described in Table 2. A difference between the mean swallowing time values for the consistencies can only be observed in the adult group ($p=0.0000$). In other words, there is no difference in swallowing time between adult and elderly individuals for the consistencies of 5ml. In the adult group, the differences were identified between: liquid and nectar, liquid and honey, nectar and pudding, honey and pudding. This analysis indicates that when the liquid and pudding consistencies are compared, there is no difference in the swallowing time for this volume. The same goes for honey and nectar. In other words, for the volume of 5 ml, the swallowing of liquid and pudding prove to be practically equivalent, just as nectar and honey, and these have longer swallowing times than the rest.

Table 2. Comparison between the four consistencies in the volume of 5 ml for each group (adult and elderly) with the ANOVA test

CONSISTENCY	ADULTS (n=72)		p	ELDERLY (n=75)		p
	Mean	Standard Deviation		Mean	Standard Deviation	
Liquid	1.24	0.11	0.0000	1.36	0.20	0.8428
Nectar	1.37	0.19		1.34	0.20	
Honey	1.41	0.15		1.37	0.20	
Pudding	1.30	0.18		1.36	0.20	

(*) Significant differences at a significance level of 0.05
ANOVA

Table 3 lists the data of the mean swallowing time analysis in adult and elderly individuals for the volume of 10ml in each consistency. The mean swallowing time in the elderly was significantly longer than that of adults for all consistencies. The mean swallowing time in both groups was longer for liquid and shorter for pudding.

The adult group revealed a difference in swallowing time for the following consistencies: liquid and honey, liquid and pudding, nectar and honey, nectar and pudding. In the elderly group, these differences were between: liquid and pudding, honey and pudding. In other words, for the volume of 10ml, adults had a shorter swallowing time for honey and pudding than for liquid and nectar. In the elderly, the swallowing time of pudding was shorter than those of liquid, nectar and honey.

Table 3. Comparison between the four consistencies in the volume of 10 ml for each group (adult and elderly) with the ANOVA test

CONSISTENCY	ADULTS (n=72)		p	ELDERLY (n=75)		p
	Mean	Standard Deviation		Mean	Standard Deviation	
Liquid	1.56	0.09	0.0000*	1.69	0.20	0.0084*
Nectar	1.53	0.27		1.66	0.24	
Honey	1.43	0.15		1.68	0.21	
Pudding	1.37	0.18		1.57	0.23	

(*) Significant differences at a significance level of 0.05
ANOVA

Table 4 describes the swallowing time values in relation to the increase in volume. Based on these values, the swallowing time difference of 5 and 10ml in each consistency, in adults and the elderly, can be calculated, which is shown in Table 5. When the time increase between adult and elderly individuals is compared (Table 5), one can see that when the volume goes from 5 to 10 ml for the consistencies nectar, honey and pudding, the observed increase in swallowing time in the elderly is significantly greater than the increase that occurs in adults. For the liquid consistencies, the swallowing time increases in the elderly group, but there is no difference when the values of the adults are compared.

Table 4. Comparison between the elderly group (GI) and the adult group (GII) regarding Time (T) for the volumes of 5 and 10 ml

CONSISTENCY	ADULTS (n=72)		ELDERLY (n=75)		p
	Mean	Standard Deviation	Mean	Standard Deviation	
Liquid 5 ml	1.24	0.11	1.36	0.20	0.0000*
Liquid 10 ml	1.56	0.09	1.69	0.20	0.0000*
Nectar 5 ml	1.37	0.19	1.34	0.20	0.3161
Nectar 10 ml	1.53	0.27	1.66	0.24	0.0040*
Honey 5 ml	1.42	0.15	1.37	0.20	0.1133
Honey 10 ml	1.43	0.15	1.68	0.21	0.0000*
Pudding 5 ml	1.30	0.18	1.37	0.20	0.0260*
Pudding 10 ml	1.37	0.18	1.57	0.23	0.0000*

(*) Significant differences at a significance level of 0.05
Student's t-test

Table 5. Comparison between the swallowing time differences of adults and elderly for 5 ml and 10 ml in various consistencies

CONSISTENCY	ADULTS (n=72)		ELDERLY (n=75)		p
	Difference between means	Standard Deviation	Difference between means	Standard Deviation	
Liquid	0.32	0.14	0.33	0.26	0.7880
Nectar	0.16	0.34	0.32	0.33	0.0048*
Honey	0.02	0.21	0.31	0.29	0.0000*
Pudding	0.08	0.23	0.21	0.33	0.0068*

(*) Significant differences at a significance level of 0.05
Student's t-test

In the data presented in Table 6, the mean swallowing times of the free volume for adults and the elderly are significantly different. The mean time in the elderly is longer than that of adults in the liquid and nectar consistencies and lower in honey and pudding. The longest time means were found for the honey consistency in both groups. In the adult group, the mean time for the free volume was shorter in the consistency nectar and higher in honey and pudding. In the elderly group, the mean time of the free volume had an intermediate value in relation to the volumes of 5 and 10 ml for all consistencies. A subsequent study is suggested to employ a method of measuring the freely ingested volume by the subjects to correlate time, volume and consistencies.

Table 6. Swallowing times for free volumes of the consistencies tested

CONSISTENCY	ADULTS (n=72)		ELDERLY (n=75)		p
	Mean	Standard Deviation	Mean	Standard Deviation	
Free liquid	1.26	0.09	1.50	0.27	0.0000*
Free nectar	1.22	0.17	1.50	0.29	0.0000*
Free Honey	1.82	0.07	1.54	0.25	0.0000*
Free Pudding	1.57	0.12	1.47	0.28	0.0104*

(*) Significant differences at a significance level of 0.05
Student's t-test

DISCUSSION

This study used Doppler Sonar to gather data on the differences in swallowing time between the populations under study and then analyzed this data with the VOXMETRIA software.

With aging, swallowing performance changes. In general, the functional reserves of various organs and systems decrease in the elderly, and this implies changes in the swallowing phases. When these individuals don't have health problems, they utilize compensatory strategies, such as applying force when swallowing and increasing the pressure of the tongue in the oral cavity to assist in food propulsion [18-21].

This study found an increase in time for most different consistencies and volumes in the swallowing of the elderly when compared to adults, corroborating the findings in the literature,[22] which state that the various characteristics of the swallowing sound depend directly on the consistency of the food, with an increased food consistency causing difficulties in the preparation and organization of the bolus, a slower manipulation, difficulties in ejection and a reduced antero-posterior movement of the tongue. The consistency and volume of the food, therefore, interferes in swallowing performance [11,13,22-24].

This study revealed that swallowing time in the elderly is longer than in adults. This conclusion has also been described by several authors as a consequence of the swallowing process being slower due to all the characteristics of presbyphagia [25,26]. In general, a subtle slowing down of the swallowing process is observed with advancing age, in addition to other changes related to the preparation of food in the oral phase, the number of swallows and the presence of residual food

along the digestive tract[27]. Several differences in occurrences and how these affect individuals can be found during aging. Its development occurs heterogeneously, and the capacity to adjust is the main characteristic of healthy aging [21,28].

In general, the swallowing time in the elderly was longer than in adults for all consistencies. However, there was no significant difference in the swallowing time of adult and elderly individuals for the volume of 5ml in the consistencies tested, i.e., for this volume, consistency has no significant influence on swallowing time. Youmans and Stierwalt (2011), [29] however, state that duration assessments with sound can suffer influences from the volume and from the material ingested[30]. The duration of the signal appears to be proportional to the volume of food ingested for both liquid and pasty viscosities[31].

For 10ml, there is a significant difference between the swallowing time means of the adult and elderly groups for the different consistencies. In adults, the mean swallowing time of liquid and nectar is longer than that of honey, which in turn is longer than pudding. In elderly individuals, the mean swallowing time of liquid, nectar and honey is longer than that of pudding. The differences found in this study between the swallowing times of the two groups are in line with other works that also studied this same population, and which concluded that a slowing of muscle movements, a dysfunction of the cricopharyngeal sphincter and the closure of the pharynx, a reduction of the elevation of the larynx and an increase in swallowing time occurs for the swallowing of healthy elderly [29,30].

Some studies suggest that more viscous substances pass more slowly through the upper esophageal sphincter [32]. Youmans and Stierwalt (2011) [29] report that adults have more muscle strength, resulting in a slower transit and increasing the swallowing time. In contrast to these findings, Im *et al.* (2012)[33] state that the viscosity of the food does not interfere with the speed of the displacement of food to the pharynx.

In this study, the mean swallowing time of the liquid and nectar consistencies increased in the elderly compared to adults in the free volume; for honey and pudding, on the other hand, the time decreased. Since the free swallowing volume wasn't measured, there may have been a decrease in the volume administered, influencing the decreased swallowing time in the elderly.

Some studies have suggested an inverse relationship between the volume of the bolus and the duration of the swallowing sound, based on the faster physiological process of the passage of the bolus through the pharynx as volume is increased [22]. When the increase of volume in different consistencies is considered in this study, the mean swallowing time in the elderly increases in the nectar, honey and pudding consistencies when compared to adults. In the elderly, the swallowing time increases in all consistencies. That is, for the elderly the increase in volume implies an increase in swallowing time in all consistencies, and this time increase is greater in relation to adults.

In the review by Cichero and Murdoch (2003)[22] on the physiological causes of swallowing sound alterations, they described that most researchers agreed that the duration of the swallowing sound signal of liquid is 500ms. When smaller amounts were swallowed (1/3 spoon of pasty food), a duration of 250ms was described. As already mentioned, Mc Kaig (1996)[17] states that the time is specific to each individual because some people may have a swallowing function that can last a total of 1s, while others do this in 3s without presenting dysphagia. In this study, the average swallowing time ranged from 1.22s (free nectar) to 1.82 (free honey) in adults, and 1.34 (5ml nectar) to 1.70 (saliva) in the elderly.

It is worth noting that the average swallowing time of saliva had values close to the 5 ml volume for adults, and the 10 ml volume for the elderly.

The Doppler Sonar revealed its ability to quantify swallowing time, but further studies are required with this methodology, and with the simultaneous association with image tests, in order to standardize the times and analyze both the swallowing sound and imaging with specific software.

CONCLUSION

There was a change in swallowing time both in relation to the consistency and the volume of the food bolus when elderly and adult subjects were compared. In the elderly, the increase in volume and consistency resulted in an increase in the swallowing time in relation to adults for the 10 ml volume. However, a more significant relation of swallowing time could be observed with volume variation than with consistency.

For therapeutic effects, therefore, the conclusion can be drawn that a decrease in the administered volume may have an equal or greater impact on swallowing time than the increase in consistency.

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APPENDIX I

Questionnaire 1

1. NAME:_____
2. GENDER: ( ) FEMALE ( ) MALE
3. AGE: _____
4. PRE-EXISTING DISEASES: _____
_____
5. HAVE YOU BEEN SUBJECTED TO CHEMOTHERAPY AND/OR RADIOTHERAPY?
( ) YES ( ) NO
6. HAVE YOU EVER BEEN SUBJECTED TO TREATMENT OF THE HEAD AND/OR NECK?
( ) YES ( ) NO
7. DO YOU HAVE ANY STRUCTURAL MODIFICATION OF THE HEAD AND/OR NECK?
( ) YES ( ) NO
8. DO YOU HAVE DIFFICULTY SWALLOWING?
( ) YES ( ) NO
9. DO YOU FEEL TIREDNESS DURING MEALS?
( ) YES ( ) NO
10. DO YOU EXPERIENCE COUGHING DURING OR AFTER MEALS?
( ) YES ( ) NO
11. DO YOU HAVE A WET VOICE AFTER MEALS?
( ) YES ( ) NO
12. DO YOU HAVE A FEELING OF FOOD STUCK IN THE THROAT?
( ) YES ( ) NO
13. DO YOU FEEL PAIN OR DISCOMFORT WHEN SWALLOWING FOOD?
( ) YES ( ) NO