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Evaluation of the location of capsules swallowed with food during the pharyngeal phase triggering in asymptomatic adults

Avaliação da localização de cápsulas ingeridas com alimentos no disparo da fase faríngea em adultos assintomáticos

ABSTRACT

Objective: To assess the location of hard gelatin capsules in the pharyngeal phase triggering among asymptomatic adults. **Introduction:** The location of the bolus during the pharyngeal phase triggering provides information about the sensorimotor model of the beginning of deglutition onset. **Purpose:** To evaluate the location of hard gelatin capsules in the pharyngeal phase triggering among asymptomatic adults. **Methods:** A videofluoroscopy swallowing study was carried out in 60 subjects (14 male and 46 female participants) aged between 27 and 55 years, who were evaluated with hard gelatin capsules #00 and #3 containing barium sulfate, swallowed with liquid food and pudding, in free volume. The first laryngeal elevation movement was the criterion to locate the pharyngeal phase triggering. Statistical analysis was based on the McNemar test. **Results:** Capsule #3 presented higher percentage of location in the tongue dorsum compared to capsule #00, and capsule #00 presented higher percentage of location in the tongue base and vallecula compared to capsule #3. There was a difference between different capsules swallowed with liquid ($p=0.016$) and pudding ($p=0.037$). **Conclusion:** The capsule size influenced the location of the pharyngeal phase triggering. Smaller capsules started pharyngeal phase in the most anterior region (tongue dorsum) compared to larger capsules.

RESUMO

Objetivo: Avaliar a localização de cápsulas gelatinosas duras no disparo da fase faríngea em adultos assintomáticos. **Métodos:** Realizou-se videofluoroscopia da deglutição em 60 indivíduos (14 homens e 46 mulheres), entre 27 e 55 anos, que foram avaliados com cápsulas gelatinosas duras #00 e #3 preenchidas com sulfato de bário, ingeridas com alimentos líquidos e pudim em livre oferta. Considerou-se o primeiro movimento de elevação laríngea como indicador do disparo da fase faríngea da deglutição. Na análise estatística, utilizou-se o teste de McNemar. **Resultados:** Cápsulas #3 apresentaram maior porcentagem de localização no dorso da língua em comparação à cápsula #00, e cápsulas #00 apresentaram maior porcentagem de localização na base da língua e valécula em comparação à #3. Foram encontradas diferenças entre as diferentes cápsulas na deglutição com líquido ($p=0,016$) e pudim ($p=0,037$). **Conclusão:** O tamanho da cápsula influenciou na localização do disparo da fase faríngea. Cápsulas menores iniciaram a fase faríngea na região mais anterior (dorso da língua) em comparação às cápsulas maiores.

Study carried out at Universidade Estadual de Campinas – UNICAMP – Campinas (SP), Brazil.

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Conflict of interests: nothing to declare.

INTRODUCTION

Swallowing is usually an ordered physiological process that involves a system of neuromuscular complexes that execute and orchestrate actions sequentially, coordinated by the cerebral cortex, cerebral trunk, and brain nerves^(1,2). This process is divided into three (oral, pharyngeal, and esophageal) or four (including the oral preparatory phase) phases⁽³⁾. The pharyngeal phase can be described as the moment in which airways are protected by the involuntary closing of the larynx by the epiglottis; by the prevention of nasal regurgitation, with the approximation of the soft palate against the posterior pharyngeal wall; by the onset of muscle contraction of constrictor pharyngeal muscles; by the movement of the bolus through the pharyngolaryngeal complex which, in that moment, is receptive for the bolus due to the amplification promoted by dilating muscles; and by the elevation and anteriorization of the whole complex, including the larynx⁽⁴⁾.

Previous studies reported that the location of the bolus in the pharyngeal phase triggering is important, because it provides information about the sensorimotor model at the onset of the swallowing process. The absence or longer duration of this process can be considered as a significant sign of dysphagia; however, the location of the bolus in the pharyngeal phase triggering can range between individuals. The onset of the pharyngeal phase depends on many factors; therefore, these data cannot be used alone to distinguish asymptomatic patients and patients with dysphagia⁽⁵⁾. This process requires fast succession of movements and coordination so that airways can be protected. Some consider it to be a chain reflex response, and others see it as a process resulting from a sequence programmed as a unit by the encephalic center⁽⁶⁾.

Studies conducted with food suggest that, among asymptomatic subjects, the onset of the pharyngeal phase can take place before the food enters the pharynx (vallecula, posterior pharyngeal wall, pyriform sinus, or pharyngeal/esophageal transition), and these locations may not be a result of changes⁽⁷⁾. Besides the study carried out with several food types and consistencies⁽⁸⁻¹¹⁾, it is important to analyze the swallowing processes of other types of materials, such as capsules, which can be swallowed with different foods. This study aimed at assessing the location of capsules of different sizes, swallowed with different food consistencies, in the onset of the swallowing pharyngeal phase.

METHODS

Participants

This study was approved by the research ethics committee (protocol no. 863/2009), and all the participants signed the informed consent. The videofluoroscopy swallowing study (VFSS) was conducted with 60 asymptomatic adults (14 men and 46 women), aged between 27 and 55 years, all of whom were volunteers recruited by the researchers.

Inclusion criteria were preserved oral sensitivity; non-use of medications that could cause collateral effects and change dietary

habits; absence of complaints or signs of dysphagia; and absence of history of central nervous system diseases, neuromuscular diseases, head and neck cancer, neurological surgery, psychiatric disorders, diabetes mellitus, or craniofacial anomalies.

Videofluoroscopic swallowing study

Subjects were assessed by the VFSS, lateral position, and were assisted by a speech-language pathologist, one radiology technician, and one radiology physician. Four hard gelatin capsules #00 (0.95 mL capacity, weighing 500–1,000 mg) and four #3 (0.3 mL capacity, weighing 200–300 mg) capsules with barium sulfate were offered to the participants, and it was possible to visualize them during the evaluations. Two capsules of each size were swallowed with liquid foods (75 cP, containing water + soluble juice power, passion fruit flavor) and two capsules of each size were swallowed with pudding (5350 cP, containing four spoons of Thick & Easy[®] thickener + 100 mL water + soluble juice power, passion fruit flavor), in free volume. Food consistency was reproduced based on studies by Sordi et al.⁽¹²⁾ and classification was based on the description presented by the American Speech-Language-Hearing Association⁽¹³⁾. For data analysis, the second swallow of each capsule and each consistency was chosen, and the first one worked as an adaptation to the examination.

Free volume is considered to be clinically important, because it provides results that are close to the customary swallowing habits of each subject. Therefore, it is an additional tool for the establishment and location — oral, pharyngeal, and esophageal — of the causes for dysphagia and odynophagia⁽¹⁴⁾.

Participants were instructed as follows: “place the capsule on your tongue, together with the customary amount of food you use when taking any medication. Face forward and swallow”.

The VFSS used dynamic x-ray images of the oral and pharyngeal phases. Patients were submitted to 5-min exposure, at most. Examinations could be analyzed afterwards, frame by frame (in milliseconds).

The VFSS was conducted in a remote controlled x-ray device (Flexavision, 800 mA, 120 kVp; Shimadzu), and all examinations were recorded in the VCR Panasonic Super-VHS PV-S7670, 25 frames a second. Participants remained standing up and the fluoroscopic tubal cannulation was done in the lateral position.

The images were evaluated with the help of software Virtual Dub (in milliseconds). Examinations were assessed by two independent researchers, who did not have access to the identity of participants. Each investigator revised each videotape and evaluated the swallowing process by adopting the slow-motion frame-to-frame analysis.

Criterion to locate the bolus

The criterion used to locate the bolus was its anatomic position, considering the head of the capsule on the dorsum of the tongue (Figure 1), on the base of the tongue (Figure 2), and in the vallecula (Figure 3).

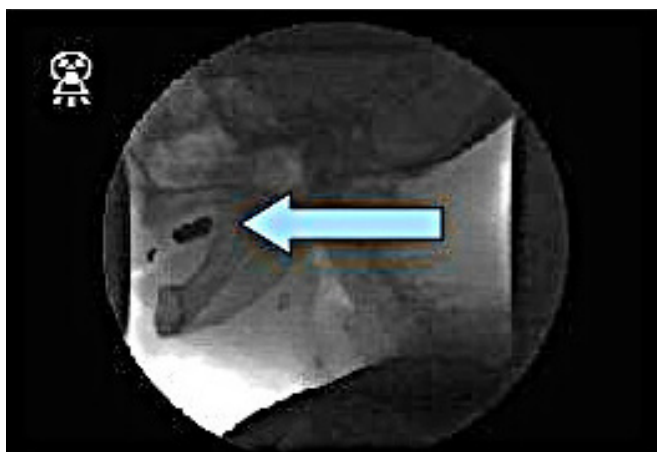


Figure 1. Head of the capsule on the dorsum of the tongue

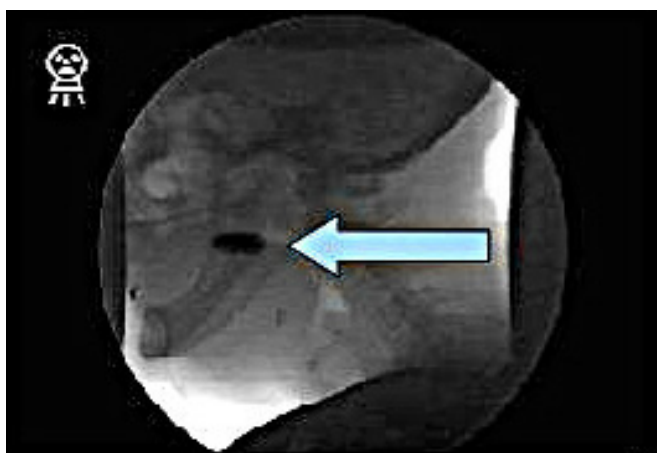


Figure 2. Head of the capsule on the base of the tongue



Figure 3. Head of the capsule on the vallecula

Statistical methodology

Intra- and inter-researcher analysis

For the intra-researcher re-evaluation, the researcher randomized, selected, and reassessed 30% of videofluoroscopy

examinations that were recorded in a digital file. For the inter-researcher re-evaluation, a second researcher analyzed 100% of the tests.

Analysis of bolus location

To analyze the location of the capsule in the onset of the pharyngeal phase, the McNemar test was used to consider paired data, considering a 0.05 significance level.

RESULTS

The results indicated that adequate reliability was reached in both intra-researcher and inter-researcher evaluations. For data analysis, the results of the first researcher were used, because they were more consistent in the intra-researcher analysis.

Comparison of food location in the onset of the pharyngeal phase

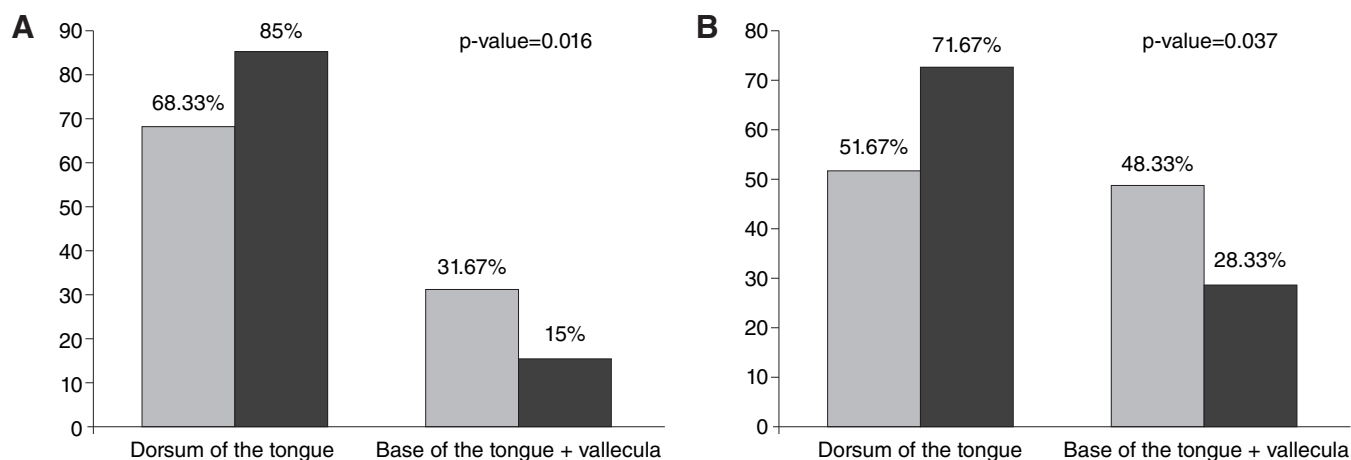
The first laryngeal elevation movement was considered as the indicator for the onset of the pharyngeal swallowing phase, by observing the location of the head of the capsule. Therefore, the following results were obtained.

Based on the results of Graphic 1, the McNemar test was carried out. Results presented differences with regard to the location of capsules #00 and #3 in the onset of the pharyngeal phase, both swallowing with liquid and pudding consistencies. The results showed higher percentage of location on the dorsum of the tongue for both capsules; however, concentration was higher when swallowing capsule #00 in comparison to #3, with differences between swallowing them with liquid or pudding. The events in the posterior portion (base of the tongue and vallecula) were different, because the concentration of capsule #3 was higher than that of capsule #00, with differences in both consistencies.

DISCUSSION

Unlike the process that takes place with food, in which larger pieces require sensory perception and motor control to allow mastication, the action of swallowing capsules requires specific neuromotor control, which enables the organization and coordination between capsules and food. Considering our major need for medications in all stages of life, the study with capsules could help and indicate the safest and most efficient way to ingest some types of drugs.

The onset of the pharyngeal swallowing phase is discussed in literature, because there is no consensus about its process. Some theories have defined it as a series of involuntary muscle movements, which are fully coordinated and controlled by the central nervous system, by using the nuclei of bulbar cranial pairs: glossopharyngeal (IX), vagal nucleus ambiguus (X), and hypoglossal nerve (XII). The impulses of these nerves are transported for reticular formation in the cerebral trunk, where the swallowing center is located, which is coordinated with the respiratory center; therefore, during the swallowing process, the breathing process is interrupted⁽¹⁵⁾.



Graphic 1. Comparison of capsule location with (A) assistance of liquids and (B) assistance of pudding consistency food

Other theories described the reflex of swallowing being triggered from specific areas of the pharynx and the larynx, such as the vallecula, the posterior pharyngeal wall, pyriform recess, or pharyngeal/esophageal transition, which are activated after a variety of stimuli (chemical, mechanic, and electrical) that would trigger a series of physiological events⁽¹⁶⁾.

The onset of the pharyngeal phase among healthy individuals can take place after the food enters the pharynx, which, alone, would not mean any change or sign of dysphagia⁽¹⁷⁾. The results found here show that, for most individuals, the onset of the pharyngeal swallowing phase took place before the capsule entered the pharynx, being more prevalent on the dorsum of the tongue, both for capsules #00 and #3.

Many authors used the head of the bolus as a point of reference for the onset of the pharyngeal phase. However, there has been no consensus as to the structure to be considered as a mark, and possible points of reference were the fauces, the vallecula, the base of the tongue and the joint of the tongue, and the mandible⁽¹⁸⁾. Despite the prevalence of the location being on the dorsum of the tongue, in this study, as well as others that were previously conducted, it was possible to observe that such a location ranged among individuals, therefore, there was not a specific location, for instance, the concept that anterior pillars (palatoglossal muscle) are the most sensitive place, and that pharyngeal response would be triggered by their stimulus^(19,20).

The location of the bolus in the onset of the pharyngeal swallowing phase can be used to clinically treat dysphagia, because this information would show the onset of the sensorimotor reflex of the process. Therefore, as previously mentioned, the location of the bolus in the onset of the pharyngeal phase can range between individuals, and it cannot be used as the only criterion to distinguish between the asymptotic swallowing and the swallowing process of the patient with dysphagia, thus suggesting that the triggering of the swallowing action depends on multiple factors.

Among these factors, there is the proprioceptive sensory perception offered by the bolus. Previous studies indicated that pharyngeal motility changed according to the nature of the

swallowed food⁽²¹⁻²³⁾ and that a more viscous consistency would be related to more neuromuscular control, in comparison to less viscous consistency, because it provides more proprioceptive stimuli that could affect the onset of the pharyngeal phase in more anterior structures, such as the base of the tongue^(24,25). This theory could not be observed in this study, because larger capsules were triggered in the pharyngeal phase at a more posterior location than the smaller ones, even though they offered more proprioceptive stimuli. This fact can be a consequence of the difficulties to control ejection and the coordination between the capsule and the food, which were aggravated by the size of the capsule.

By considering that the oral cavity is filled with sensory receptors that can transmit specific patterns and intensities and lead information to the swallowing centers in the central nervous system⁽⁶⁾, the size of the bolus could affect the organization and ejection of the food⁽²⁶⁾. However, in this study, the smaller capsule generated less perceptible stimulus, however, it resulted in the onset of the pharyngeal phase at a more anterior location.

Previous studies conducted with different volumes of bolus concluded that the higher or lower perception of food in the oral phase did not interfere in the strength modulation of the tongue⁽²⁷⁾, in the rate or duration of the maximal hyoid bone elevation⁽²⁸⁾, or in the duration of the submentonian or infrahyoid electromyographic activity⁽²⁹⁾. Another study also observed that the time interval between the initial movement of hyoid anteriorization and the arrival of the bolus to the pharynx remained constant, despite the change in the volume⁽³⁰⁾. Even though the objectives were different, the findings in this study are different from those in the previously mentioned analyses, because the volume of the swallowed material interfered in the results.

In this study, we considered the capsule as a reference, and not the food that was swallowed with it. Therefore, the comparison of the location of the pharyngeal phase triggering in our study may not be compared to other studies that used food as a reference.

The food used to help participants swallow the capsules promoted laryngeal elevation; therefore, we cannot attribute

the onset of this process to capsules. However, it is relevant to observe its different locations, because capsules of different sizes are placed in different locations, which showed that the sensory perception and the organization and coordination between capsules and food were different according to their specificities.

This study compared capsules of different sizes (#00, 23.4-mm long and 8.57 in diameter, similar to those used for amoxicillin, and #3, 15.7-mm long and 5.86 in diameter, similar to those used for omeprazole) swallowed with the same food consistency. Observing the different locations, both in the presence of liquid and pudding consistencies, is relevant to see if there are changes caused by the size of the capsule, which is proved by the obtained results. The fact that we compared different sizes of ingested capsules with the same food consistency showed that the size of the capsule interfered in the location of the onset of pharyngeal elevation, which is important to give recommendations to the patient who uses this type of medicine.

Other studies about swallowing capsules should be carried out, because literature is scarce. Studies in this field can provide additional information to assist pharmaceutical industries and patient care.

There are some methodological limitations of this study, for instance, the discrepancy between participants from both genders, the nonuniform distribution of different age groups, the free volume of food, which ranged between participants, and the nonpossibility of visualizing the food (non-contrast). More studies, with larger samples, are necessary so that normative references can be found.

CONCLUSION

The size of the capsule influenced the location of the pharyngeal phase triggering, and smaller capsules presented higher percentage of location at a more anterior region (dorsum of the tongue), in comparison to larger capsules, both with swallowing liquid and pudding consistency food.

**EMTU was in charge of data collection, tabulation, and analysis, as well as the elaboration of the manuscript; DBP collaborated with data analysis; LFM, IHKB, and ANC were responsible for the study design and general orientation of the stages of execution, as well as the elaboration of the manuscript.*

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