Swallowing quantitative analysis software*

Software para análise quantitativa da deglutição

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Abstract   **OBJECTIVE: The present paper is aimed at introducing a software to allow a detailed analysis of the swallowing dynamics. MATERIALS AND METHODS: The sample included ten (six male and four female) stroke patients, with mean age of 57.6 years. Swallowing videofluoroscopy was performed and images were digitized for posterior analysis of the pharyngeal transit time with the aid of a chronometer and the software. RESULTS: Differences were observed in the average pharyngeal swallowing transit time as a result of measurements with chronometer and software. CONCLUSION: This software is a useful tool for the analysis of parameters such as swallowing time and speed, allowing a better understanding of the swallowing dynamics, both in the clinical approach of patients with oropharyngeal dysphagia and for scientific research purposes.**
Keywords: Swallowing videofluoroscopy; Software; Quantitative analysis.

Resumo   **OBJETIVO: Apresentar um *software* que permita uma análise detalhada da dinâmica da deglutição. MATERIAIS E MÉTODOS: Participaram deste estudo dez indivíduos após acidente vascular encefálico, sendo seis do gênero masculino, com idade média de 57,6 anos. Foi realizada videofluoroscopia da deglutição e as imagens foram digitalizadas em microcomputador, com posterior análise do tempo do trânsito faríngeo da deglutição, por meio de um cronômetro e do *software*. RESULTADOS: O tempo médio do trânsito faríngeo da deglutição apresentou-se diferente quando comparados os métodos utilizados (cronômetro e *software*). CONCLUSÃO: Este *software* é um instrumento de análise dos parâmetros tempo e velocidade da deglutição, propiciando melhor compreensão da dinâmica da deglutição, com reflexos tanto na abordagem clínica dos pacientes com disfagia como para fins de pesquisa científica.**
Unitermos: Videofluoroscopia da deglutição; *Software*; Análise quantitativa.

INTRODUCTION

The swallowing dynamics includes the coordination and interaction of several muscles and nerves involved in the four phases of this process: oral preparatory phase, oral phase, pharyngeal phase and esophageal phase[1]. These interrelated phases compose a complex dynamic process based on a sophisticated neuromotor control. The phases synchronism allows the food transit from the mouth to the stomach without tracheal penetration or aspiration.

Any alteration in the swallowing dynamics is called oropharyngeal dysphagia. Dysphagia may be related to neurological, mechanical, psychogenic, iatrogenic or idiopathic disorders. Buchholz[2] has defined neurogenic oropharyngeal dysphagia as a result from a motor and sensorial disorder, affecting the oral and pharyngeal swallowing phases.

The clinical evaluation of the deglutition depends on the investigator's knowledge about the anatomical structures and neurophysiologic processes involved in this function which are essential for understanding the phases interrelation and for aiding in the clinical and therapeutic rationale[3]. The clinical evaluation should include anamnesis data and specific procedures to assess the phases of the swallowing function; some cases, however, require objective examinations to aid in the definition of the therapeutic conduct.

Fluoroscopy allows a real-time visualization of internal structures, but is a limited method in cases where further evaluation is required. The necessity of recording the fluoroscopic images has lead to the development of videofluoroscopy where the fluoroscopic images are recorded on videotapes or other recording medias. This process has reduced the radiation exposure both for patients and radiologists[4].

Presently, swallowing videofluoroscopy is considered as the method of choice in the evaluation of the swallowing dynamics allowing visualization of the whole process (oral preparatory, oral, pharyngeal and esophageal phases). However, it is important to note that this method allows only a qualitative evaluation of the swallowing dynamics.

The two-dimensional videofluoroscopic images are defined by the interaction between X-rays and the different densities of the several structures of the region evaluated, allowing their recording in a VHS tape. The identification of the structures and the understanding of their real function depend on an appropriate knowledge of anatomy and capacity of identifying the dynamic structures repositioning through their densities displacement.

Digital radiological equipment allow the acquisition of images with a better quality; however, the non-availability of such equipment does not hinder an objective evaluation of the deglutition mechanism. The literature has described softwares for images digitization allowing a more accurate analysis besides reducing the cost.

The present study was aimed at introducing a software for acquisition of quantitative parameters to allow a more objective analysis of the swallowing dynamics, covering aspects such as the transit time over the whole process and residual area in the pharyngeal recess by means of videofluoroscopic images.

MATERIALS AND METHODS

Patients

The present study included ten (six male and four female) right-handed patients in the age range between 44 and 82 years (mean age = 57.6 years), who had suffered cortical cerebral vascular accident (CVA).

Exclusion criteria were the following: patients with hemorrhagic CVA with decrease in the consciousness level, and patients presenting with unstable clinical conditions confirmed by medical evaluation.

The present study protocol was approved by the Committee for Ethics in Research of Hospital das Clínicas da Universidade Estadual Paulista Júlio de Mesquita Filho (Unesp), and all patients included in the protocol signed a term of free an informed consent.

Method

The methodology included a clinical-neurological evaluation, involving anamnesis and personal antecedents, and also neuroimaging studies (computed tomography and/or magnetic resonance imaging). The studies requested as part of the assistance routine were interpreted by clinicians, neuroradiologist and neurologist, and also by a speech-language therapist. The patients were also submitted to videofluoroscopy for evaluation of the swallowing dynamics.

The videofluoroscopic studies were cooperatively performed by a radiologist and a speech-language therapist. The radiological evaluation of the deglutition involves a fluoroscopic study with deglutition of food modified with barium sulfate (contrast agent).

The equipment was a remote control General Electric Prestilix model 1600X, 1000 mA, 130 kV. The coupled collimator allowed 35 cm × 43 cm maximum aperture, with possibility of total shutter. The examination table remained at 90º angle for these examinations. The images were transmitted to a Sony PVM-95E video monitor, and simultaneously to a Panasonic SVHS AG 7400 video cassette recorder coupled with a Leson Sm-58 microphone for audio recording, improving the documentation of the method utilized at each deglutition and, consequently, facilitating the later analysis of the images.

Videofluoroscopic images were acquired in lateral projection views, with the patients seated upright in a feeding position, imaging from the oral cavity to the esophagus. Each patient was observed during the deglutition of 5 ml food with a pasty consistency offered in a spoon.

Digitization was performed at an acquisition rate of 29.97 frames/second to allow the evaluation of the bolus positioning at each 33 ms. Later, these images were processed in a computer. At a first moment, the bolus transit time was evaluated with the aid of a manual chronometer, and after, with a software developed by post-graduation students of the Department of Neurology and Psychiatry of Unesp, Botucatu, SP, and Department of Electrical Engineering of Universidade de São Paulo, São Carlos, SP. This software allows the recording of the transit time in milliseconds by means of the frames analysis on the screen and the swallowing events sequencing.

A comparative analysis was performed between the results from the measurements with the manual chronometer and the software. The analysis of the chronometer measurements considered the onset and the end of the bolus transit through the pharyngeal phase, corresponding to the duration of each phase. On the other hand, with the software, this analysis was based on the frames counting and also on the onset and end of the pharyngeal phase. The pharyngeal phase onset corresponded to the moment where the bolus reached the posterior nasal spine, at the end of the hard palate and beginning of the soft palate; the end of the pharyngeal phase was marked during the bolus transit through the upper esophageal sphincter[5].

The software itself is very simple, and its confidence level is exclusively operator-dependent. In the case of the present study, the operators were the speech-language therapists who were able to evaluate the swallowing dynamics by means of videofluoroscopy. A status bar including the present status and several information on the study as a whole is displayed at the bottom of the main window.

The main resource of this software is the tool for time measurement already exhaustively tested. Additionally, there is a second tool to evaluate the residual area, but this tool is yet to be improved and validated.

In the evaluation of the time elapsed between the swallowing events, where a quantitative data is required, the application utilizes functions based on the frames comprising the study (film format file) for time calculation. On the progression bar, the observer may choose an initial point in time, making more precise adjustments by means of the manual advancement on a step-by-step basis, changing the number of frames to be advanced at each step of the process.

Once an initial point is selected, identifying the swallowing event onset, the observer activates the command to record the event onset. Upon this command, the ap-

plication offers two additional options: one, to record the end of the swallowing event; and another to clear the saved data.

The end of the swallowing event recording only should be performed when the exact frame corresponding to the end of the event is displayed. Then, the application will display the time elapsed in three ways: The first one, shows the number of frames of the event, the second, displays the time in seconds, and the third displays a more precise timing in milliseconds.

Another resource of the application is the zoom option, to enlarge the visualization area for each frame. The details of this process are shown on Figure 1.

RESULTS

Different values were found in the comparison between the mean pharyngeal transit times measured with the chronometer and the software. The patients in this group presented mean transit times of 4.6 s and 2.5 s respectively with the chronometer and the software (Figure 2). This difference may be understood as the latency for visual recognition and the manual chronometer activation. Obviously the level of attention of the investigator also affects the measurements accuracy.

It could be observed that the software allows a more accurate measurement, considering the possibility of the precise detailing and identification of the onset and the end of the pharyngeal phase. The divergent values corroborate the necessity of more precise tools to evaluate the pharyngeal transit time by means of videofluoroscopic images. In the present case, the software has allowed this evaluation.

DISCUSSION

The initial idea for the development of this tool resulted from the need for quantifying and measuring the swallowing process, not as whole, but as segments, measuring the transit time at each swallowing phase. The software allows a dynamic analysis (real-time execution), and a static (frame to frame) analysis of the deglutition.

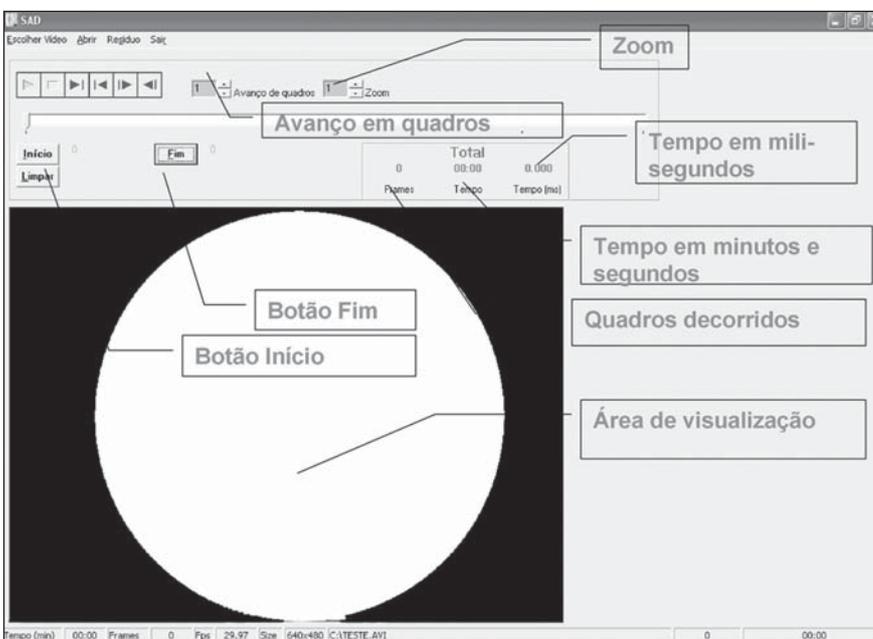Te divergent values between chronometer and software measurements demonstrated that the transit time evaluation based

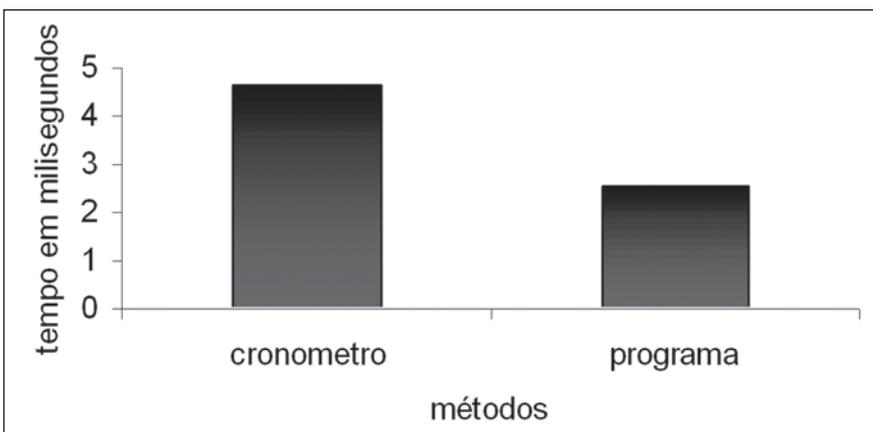**Figure 1.** Visualization of some of the tools available in the application software.

Figure 2. Comparison between pharyngeal phase transit times measured with manual chronometer and the software.

only on videofluoroscopic images is not accurate. More precise tools utilizing specific applications allow a more accurate, fast and reproducible measurement, and are essential both for utilization in the clinical assistance and new academic studies and literature reviews.

Accuracy becomes significant when the objective is to evaluate the efficacy of therapeutic procedures in the rehabilitation process involving dysphagic patients. The rehabilitation follow-up becomes more effective with the utilization of the software. In the analysis of the swallowing dynamics, the differences in the transit time for each phase are minimal, and therefore in-

appropriate for visual and mechanical analysis.

Considering the poor quality of the video images and the absence of a digital equipment, there was the necessity of the software fore a more accurate quantitative analysis of the swallowing phases timing.

Studies about videofluoroscopy, comparing methods of swallowing dynamics quantitative analyses have not been found in the literature.

Studies like the one developed by Kendall et al.[5] utilize application softwares to measure the bolus transit time over the different swallowing phases in healthy individuals. In the present study, post-CVA

patients presented a higher mean pharyngeal transit time when compared with the healthy individuals of that study, where the mean pharyngeal transit time with a paste consistency bolus is 0.91 s. This difference is a result of the presence of oropharyngeal dysphagia in the patients evaluated in this study.

It may be observed that, for timing analyses in swallowing videofluoroscopy, it is necessary to utilize a software to allow a precise identification of internal structures involved in the onset and end of each swallowing phase. According to Kendall et al.[5], the pharyngeal phase onset corresponds to the moment where the bolus reaches the posterior nasal spine, at the end of the hard palate and beginning of the soft palate. An accurate determination of the different swallowing phases with a manual chronometer is unfeasible.

Martin-Harris et al.[6], in a study with digitized videofluoroscopy, have analyzed the movements of anatomical structures such as the hyoid bone during the deglutition, correlating their timing with sex and racial groups. In this study the analysis is limited by the method (measurement without the utilization of a software), considering the accuracy and swiftness of the swallowing movements whose individualization is unfeasible.

Other authors, such as Santoro et al.[7], have reported a quantitative evaluation of the swallowing dynamics in a healthy elderly population utilizing swallowing endoscopy with the Adobe Premiere 6.0 application for images editing. In this study, the moments for starting the recording of the oral and pharyngeal phases are determined, with a mean transit time for the pharyngeal phase $= 867.8 \pm 157.8$ ms (minimum 567 ms and maximum 1133 ms). However, considering that the data are related to the swallowing endoscopy, the comparison with the method described in the present study was not feasible. The mentioned application includes tools for time elapsed evaluation, besides other complex video features considered as non-relevant in our experiment whose main objective was to be focused on the video in execution for identification of relevant aspects. For this reason, the application software described in the present study was developed with a more clean and clear interface for timing evaluation.

The absence of similar application softwares does not allow a comparative analysis. The sole analysis method commercially available utilizes morphological and functional parameters similar to those of the application software described in the present study, but applies different softwares and records.

CONCLUSION

This application software offers a comprehensive tool for parametric analysis of the swallowing timing and speed, resulting in a better understanding of the swallowing dynamics, affecting both the clinical approach to patients with oropharyngeal dysfunction and the scientific research. Additionally, the resources of this application allow an individualized interpretation of the swallowing phases which otherwise would be unfeasible with the conventional, subjective analysis methods subject to interobserver variations. Further studies will be necessary to minimize or eliminate the subjectivity in the determination of transition points between the different swallowing phases.

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