SURFACE ELECTROMYOGRAPHY PROTOCOL FOR THE ASSESSMENT OF HUMAN SWALLOWING

D. M. Garcia[a,b], A. Mapelli[a,b], G. A. Folha[a,b] A. S. Gaido[a,b], F. C. P. Valera[a,b], L. V. V. Trawitzki[a,b] and C. M. Felício[a,b]

[a] Department of Otorhinolaryngology, Ophthalmology, and Head and Neck Surgery. Ribeirao Preto Medical School, University of São Paulo, Brazil
[b] Craniofacial Research Support Center - University of São Paulo

email: dmgarcia@fmrp.usp.br

Abstract: The surface electromyography (sEMG) application to the study of voice, speech, and swallowing is becoming increasingly popular. A standardized protocol for concomitant sEMG assessment of supra-hyoid muscle activity during deglutition was proposed. The study included 15 healthy volunteers from the community, aged between 21 and 43 years. Simultaneous bilateral sEMG activity from supra-hyoid muscle areas was performed by placing two electrodes. Different swallowing conditions were evaluated: spontaneous swallowing of saliva, voluntarily triggered swallows of 10 ml and 15 ml of water and spontaneous swallowing of a standardized biscuit. The main parameters proposed were: deglutition time, border amplitude, maximum peak amplitude, first maximum peak velocity, maximum peak delay and signal integral. The parameters analyzed in this study were able to compare different consistencies and volumes of the bolus during swallowing. We believe that those parameters will be useful in further researches with patients of different pathologies.

Keywords: swallowing, surface electromyography, biomedical signal analysis.

Introduction

The surface electromyography (sEMG) application to the study of voice, speech, and swallowing is becoming increasingly popular [1]. Specially for assessing the activation of swallowing muscles sEMG methods have already been used [2] with an advantage in relation to the other techniques that is noninvasive, time-saving and enables measurement of muscles activity, providing data to physiologists and clinicians about the physiology of the skeletal muscle during voluntary contractions [3] with no radiation and a negligible discomfort [4].

The sEMG, when used in proper and detailed standardized protocols, with established normative database, can be a useful, reproducible and reliable screening method for the assessment of swallowing disorders [4, 5]. Thus, it will improve future research and clinical applications [1], quantify and regularly monitor the patients with suspected of swallowing disorders [4, 5], proving a simple diagnostic screening [6], because previous data have shown a sEMG activation strictly connected to the swallowing biomechanical events [7].

Although the sEMG has been studied for years in numerous studies, there are important discrepancies between different authors, regarding some of the basic aspects of the act of swallowing common to all subjects [4]. Also, a quantitative and noninvasive evaluation of the entire sequence of the oropharyngeal swallowing process remains to be established, for to promote a differentiating between the values that represents normal and abnormal function [4, 8]. Quantitative studies of swallowing are necessary to gain insight into the mechanisms by which saliva, fluids, and solids of different consistencies are swallowed [9]. This insight might facilitate identification of the specific problems children and adults with dysphagia of different etiology, and can support mechanism-based explanations for dysphagia [9].

Furthermore, sEMG studies of deglutition may be further improved by international standardization, since have been found a large variation in examination techniques, strategies, interpretations, diagnostic criteria and electromyographers [6]. The lack of standard requirements decreases the outcome of this investigation technique significantly. In the case of sEMG evaluation of deglutition the protocol might be based on: protocol application, protocol requirements for diagnostic equipment, protocol technique, protocol tests, normative database and standard analysis [6].

This study presents a standardized protocol for sEMG assessment of supra-hyoid muscle activity during deglutition, and investigates the relationship between parameters and several kinds of deglutition tasks.

Materials and methods

The study was approved by the local Ethics Committee (HCFMRP-USP 12634/2010) and all subjects gave written informed consent to participate. The study included 15 healthy volunteers from the community, aged between 21 and 43 years (mean age of 29.7 ± 7.0), including 5 males and 10 females, who reported no complaints to swallow, with no changes in the orofacial myofunctional system or the scapular region, with no signs of temporomandibular changes, with complete permanent dentition (or absence/ extraction of the third molars was allowed), an Angle Class I molar relationship and absence of severe malocclusion. The exclusion criteria were: neurological or cognitive deficit, previous or current tumors or traumas in the head and neck region, current or previous orofacial myofunctional therapy, current use of analgesics, psychiatric drugs and muscle relaxants. The absence of changes in the orofacial myofunctional system and of signs of temporomandibular was determined by the application of the standard clinical protocol of orofacial myofunctional evaluation with scores (OMES-E) [10] and standard Protocol for Multi-Professional Centers for the Determination of signs and symptoms of temporomandibular disorders (TMD) (ProTMDMulti-Part II) [11], respectively.

Simultaneous bilateral sEMG activity from supra-hyoid muscle areas were performed by placing two couples of disposable silver/silver chloride unipolar pre-gelled electrodes (diameter 10 mm, interelectrode distance 21 ± 1 mm; Duo-Trode; Myo-Tronics Inc., Seattle, WA. USA) on the muscular bellies parallel to muscular fibers, according to the recommendations of SENIAM (Surface EMG for Non-Invasive Assessment of Muscles) (Figure 1). EMG activity was recorded using a wireless electromyographic system (FreeEMG, BTS S.p.A., Garbagnate Milanese, Italy). The analog EMG signal was amplified and digitized (gain 150, 16-bit resolution, sensitivity 1 uV, temporal resolution 1 ms – 1KHz) using a differential amplifier with a high common mode rejection ratio (CMRR > 110 dB in the range 0-50 Hz, input impedance > 10 GΩ). All the recorded EMG signals were digitally band pass filtered between 80 and 400 Hz with a 2nd order Butterworth filter, and rectified by calculating the root mean square (RMS) in temporal window of 25 ms; the software adopted to the scope was the SMART Analyzer (BTS S.p.A.).

Different swallowing conditions were evaluated: spontaneous swallowing of saliva, voluntarily triggered swallows of 10 ml and 15 ml of water and spontaneous swallowing of a standardized biscuit at the end of its mastication.

The swallowing test was conducted once for one biscuit and, twice for 10 ml, 15 ml and spontaneous swallowing. Each volume was delivered randomly and there were "intervals" (1 min) between each experiment. For 10 ml and 15 ml tasks, the subject was asked to leave the water in the mouth and after the command to "swallow", the subjects could perform swallowing habitually. For the biscuit the subject was instructed to chew in the usual manner and to swallowing when and how times were necessary, ever in the usual manner. In the swallowing spontaneous task, the subject was asked to look for a camera for 60 seconds approximately, and in this time he/she can to move and to swallowing if necessary, and thus, the swallowing spontaneous task could be performed without specific order for be conducted. All tasks with water were performed with the water in room temperature.

Figure 1: The electrodes were placed on the supra-hyoid muscles. Data analysis was aided by the visualization of 3 video cameras, one frontal and two laterals.

For each swallowing task, the onset and offset of the deglutition-related supra-hyoid muscles activity was detected by a semiautomatic computer-assisted identification [12]. The same skilled operator performed these procedures in all subjects, aided by the visualization of 3 video cameras, one frontal and two lateral, as shown in figure 1, that recorded the movement of the epiglottis during swallowing concomitant with sEMG. In particular, the onset event was detected as soon as the signal of the first muscle rose clearly above the preceding background activity. The offset event was marked when the second of the two signals returned to levels of background activity (Figure 2). Right and left muscle signals were then averaged within these two border events. Whenever performed, multiple deglutition was detected within the single swallowing condition, if separated by a gap smaller than 2 seconds [13].

The time interval between the beginning (onset) and the end (offset) of the specific deglutition determined the deglutition time (DT). For amplitude evaluations, a standardization of all the signals was applied considering the maximum peak of spontaneous saliva swallowing amplitude as the 100% value. The amplitude values were extracted from the initial, (BA-onset), final (BA-offset) and maximum peak (MPA) events of each standardized signal. The mean of BA-onset and BA-offset was calculated and defined as border amplitude (BA). For the latter, the time delay from the beginning to maximum peak moment was also computed (MPD), as well as the differential of time between the maximum peak and the offset event and

MPD, defined as post-pre time (PPT). The integral of the signal (INT) between onset and offset, and the first peak bottom-up maximum velocity (FPMV) (%/s) were also computed for each deglutition (Figure 2).

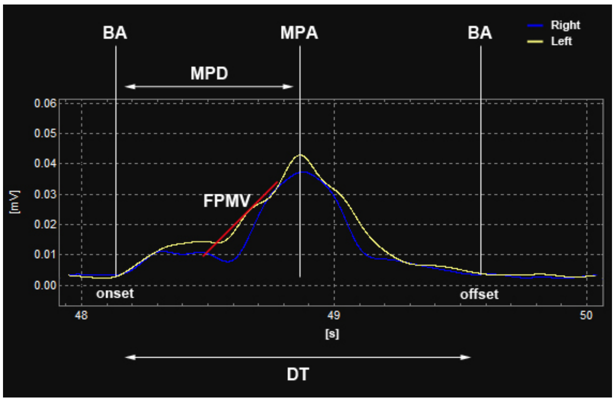

Figure 2: sEMG signal example of supra-hyoid muscles during swallowing. The parameters evaluated are schematically represented by abbreviations. BA: border amplitude; DT: deglutition time; FPMV: first peak maximum velocity; MPA: maximum peak amplitude; MPD: maximum peak delay.

One-way analysis of variance for repeated measures (cross-over ANOVA) was employed for each variable to check for differences among the swallowing tasks. Only for the border amplitudes, a 2-way ANOVA was used to directly compare the initial and final standardized amplitudes as a further factor. Significant ANOVAs were followed by post-hoc Student's t-paired test. The level of significance was set at $p < 0.05$ for all statistical analyses, using Bonferroni's correction for post-hoc tests. All statistical calculations were made using SPSS Statistics software (SPSS Inc., Chicago, USA).

Results

There was no difference between BA-onset and BA-offset amplitudes intra-deglutition tasks ($p = 0.219$).

Significant inter-deglutition task differences were found for the parameters border amplitude, maximum peak amplitude, first peak maximum velocity, integral, time and maximum peak delay ($p < 0.01$). There was no difference for the parameter PPT ($p = 0.124$).

The solid deglutition task had a larger initial and final amplitudes, maximum peak amplitude, first peak maximum velocity and integral than the all the others deglutition condition ($p < 0.01$). See Table 1 for details.

Table 1. Mean for each parameter in the different deglutition tasks.

n = 15	Deglutition Task			
	Spon.	**Solid**	**ml 10**	**ml 15**
BA [%]	14.7^{a}	33.7^{b}	16.4^{c}	19.1^{c}
MPA [%]	100^{a}	222.8^{b}	105.6^{a}	106.1^{a}
FPMV[%/s]	535.7^{a}	1362.8^{b}	608.8^{a}	618.1^{a}
DT [s]	1.07^{a}	1.03^{a}	1.13^{a}	1.06^{a}
MPD [s]	0.50^{a}	0.34^{b,c}	0.56^{a,b}	0.51^{a,b}
PPT [s]	0.07	0.34	0.02	0.03
INT [%*s]	50.3^{a}	111.9^{b}	55.3^{a}	53.9^{a}

Different letters indicate significantly differences between modalities in the post hoc tests for one-way ANOVA. BA: border amplitude; MPA: maximum peak amplitude; FPMV: first peak maximum velocity; DT: deglutition time; MPD: maximum peak delay; PPT: post-pre time; INT: integral of the signal.

Discussion

In this study young and healthy subjects were evaluated, because compared to population with dysphagia, there is a more consistent sequence of motor activity during deglutition [14]. Furthermore, the duration of the mean amplitude value of the sEMG activity is more affected by the consistency of the bolus than by gender or age [9]. Therefore, from the results found in this study, studies involving patients with impaired swallowing become feasible, using for this the methodology used here.

There was no difference between onset and offset amplitudes intra-deglutition tasks. This result shows that muscle activation does not differ between the start and end times of swallowing movement. Considering different tasks, we found border amplitude greater in solid swallowing. In that task the musculature is contracting in the period that precedes the swallowing movement, both on account of chewing solid bolus or lowering the mandibular.

In the same way, the maximum peak amplitude of muscle contraction, the first peak bottom-up maximum velocity and the signal integral were greater for solid deglutition. In the oral phase, pressure of the tongue, control of the bolus, and submental muscle group activity are important components of efficient swallowing that are mainly influenced by the consistency of the bolus [9]. Thus, the sEMG activity of supra-hyoid muscles is different when individuals swallow saliva or water [9]. However, Ding et al (2003) [15] found significant consistency effects for maximum and average amplitude and duration of the submental muscle group. Oral pressures produced by tongue-to-palate contact have been shown to increase with thicker consistencies [16].

We found that the maximum peak delay occurred before in solid task than in the others. The explanation for that could be the fact that during the stage of transport of the solid bolus oropharyngeal level, the upper airways remain open during chewing while chewed portions of the material arrive sequentially and accumulate in the pharynx [17].

The deglutition time corresponds to the duration of the propulsive action of the tongue and the elevation of the epiglottis during the oral and pharyngeal phases of swallowing. This procedure is not affected by thicker consistencies and, therefore, no differences were found between the tasks.

Conclusion

Studies have described evaluation methods of EMG during swallowing, but few employ signal normalization techniques, or analyse few parameters, failing to appreciate a greater amount of information of biological phenomena that occur during swallowing. A standardized protocol for sEMG assessment of suprahyoid muscle activity during deglutition is necessary to provide reproducible, reliable and comparable data to investigate the relationship between parameters and several kinds of deglutition tasks. We believe that the standardized protocol presented will be useful in further researches with patients in different pathologies.

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