Changes in the excitability of corticobulbar projections produced by intraoral cooling with ice

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1 Table and 2 Figures

Abstract

Objectives: The aim of our study was to assess the effects of ice applied to the oral cavity on the excitability of the corticosbulbar output to the swallowing muscles.

Methods: Eight healthy adult volunteers (mean age: 29.0 +/- 4.9 yr) participated. Motor evoked potentials (MEPs) were recorded from suprahyoid muscle complex via surface electrodes. Two blocks of 20 MEPs using a test stimulus intensity of 120% of resting motor threshold were recorded at rest (baseline). Participants then received 5 min of one of three different types of thermal stimulation: 1) “ice-stick – inside mouth”, 2) “ice-stick – neck”, 3) “room temperature – inside mouth”. Blocks of 20 MEPs were then recorded immediately and at 5min intervals for the following 15 min.

Results: There was a significant difference in the effect of the three interventions on the amplitude of the MEPs following stimulation (two way ANOVA: INTERVENTION x TIME; $F_{8,84}$=3.76, $p<0.01$). One-way ANOVA was used to evaluate changes over time for each intervention types. Only “ice-stick – inside mouth” increased MEPs (one way ANOVA main effect of TIME: $F_{4,28}$=4.04, p=0.01), with significant differences between baseline and P0 ($p<0.05$), P5($p<0.01$) and P10 ($p<0.01$). There was no significant effect of either “ice-stick – neck” or “room temperature – inside mouth” ($F_{4,28}$=1.13, p=0.36; $F_{4,28}$=1.36 p=0.27, respectively).

Conclusions: Ice stimulation within the oral cavity increases the excitability of the cortical swallowing motor pathway.

Key words: swallowing, temperature, reaction time task, motor evoked potential

Introduction

Swallowing is a complex sensorimotor activity that depends on a hierarchical interaction between the cerebral cortex, the brain stem swallowing center, and cranial nerves V, IX, X, and XII. The process of swallowing has both volitional and reflexive components, reflecting central pathways within swallowing centers in the cortex and brain stem, respectively. It is also highly dependent on sensory feedback for both initiation and modulation of the patterned sequence of neuromuscular events [1]. In fact, it is well established that sensory input is crucial to the initiation and modulation of normal swallowing, this perhaps being best demonstrated by studies with surface anaesthesia of the oropharynx which produces dysphagia in healthy human subjects [2] [3].

Transcranial magnetic stimulation (TMS) has recently been used to map the normal pattern of motor cortex projections to a number of swallowing muscles in healthy adult humans by evoking and mapping responses in oral, pharyngeal, and esophageal musculature via electromyography (EMG) [4]. Several studies have demonstrated that alterations in sensory input to the swallowing system can change excitability within the cortico-bulbar pathway. For example, it has been shown that cranial nerve stimulation can facilitate pharyngeal motor evoked potentials (MEP) evoked by TMS of human swallowing motor cortex [5]. Fraser and colleagues reported that cortical excitability associated with swallowing decreased after anesthesia [6]. Furthermore, cortical swallowing pathways are similarly modulated by both sweet and bitter tasting stimuli [7].

A major sensory modality is temperature. The time to trigger the pharyngeal phase of swallowing is shorter for cold and hot water than for normal temperature

water [8]. Similarly, Michou et al. reported that cold water shortened the latencies of normally paced swallows compared with room and hot temperatures [9]. Furthermore, Logemann has proposed that thermal stimulation increases oral awareness via an alerting stimulus to the pharyngeal swallow resulting in increased speed of initiation of swallowing at the oral cavity [10]. Studies have also reported that the pharyngeal phase of swallowing is shortened by thermal stimulation in nondisabled subjects [11] [12] [13]. However, the effects of temperature on the central control and regulation of swallowing remain unexplored.

The aim of our study was to assess the effects of ice stimulation applied to the oral cavity on the excitability of the swallowing motor pathway.

Materials and Methods

Participants

Eight healthy adult volunteers (mean age: 29.0 +/- 4.9 yr) participated in the study. All met inclusion criteria for participation in magnetic stimulation studies, i.e., no previous brain or throat surgery; no contraindications to magnetic stimulation, including a cardiac pacemaker in situ or history of epilepsy; no use of any drugs that influence the central nervous system (CNS) such as antidepressants, antiepileptics, or sleeping pills; and not pregnant. None of the volunteers reported any swallowing difficulty past or present. Approval for the protocol was granted by the UCL Research Ethics Committee, and all studies were conducted in the clinical laboratory of the Sobell Department of Motor Neuroscience and Movement Disorders at UCL Institute of Neurology (London, UK).

Thermal stimulation

We performed thermal stimulation using a 4-inch-long, 0.5-inchdiameter water-impregnated cotton-tipped stick (ice stick). The stick was either impregnated in ice water (ice stick) or room temperature water. Stimulations consisted of the repetition of 20 sec of thermal stimulation followed by a single swallow of saliva from the participant (total of 15 swallows), for a total duration of 5 min. Three different types of stimulation were performed: 1) “ice-stick – inside mouth”, 2) “ice-stick – neck”, 3) “room temperature – inside mouth”. For the condition “ice-stick-inside mouth”, subjects received ice stimulation where the ice stick touched the posterior tongue and tongue base, velum, and posterior pharyngeal wall. For the condition “ice-stick -neck”, subject received an ice stimulation of the surface of the right or left side of the neck (depending on the stimulated hemisphere). For the condition “room temperature - inside mouth”, the cotton tipped stick was moistened in room temperature water and subjects received stimulation to the posterior tongue and tongue base, velum, and posterior pharyngeal wall.

Cortical Stimulation

Cortical stimulation was performed using a magnetic stimulator (Magstim 200, The Magstim, Whitland, UK) connected to a figure-8 coil with an outer diameter of 70 mm placed over the regions of interest on the scalp as previously described [4]. In this configuration, the maximum magnetic field generated by the stimulator was 2.2 T.

Submental Muscle Electromyographic Responses

The procedures in this study followed a previous report [14]. A pair of bipolar surface

electrodes were prepared with conductive gel and placed on the right and left suprahyoid muscle complex, each 1 cm lateral to the midline. The interelectrode distance was 2 cm for each pair of electrodes, measured from the center of the electrodes. Correct placement was verified by asking the subject to maximally contract the muscles of interest (by performing a tongue press against the hard palate) while the investigator monitored online EMG activity.

Experimental Protocols

For each study, volunteers sat comfortably in a chair. Electrodes were first positioned according to the above described method. The cranial vertex was then identified according to the international 10–20 system for electrode placement and marked on the scalp. The optimum site for evoking MEPs in the suprahyoid muscle was then determined by discharging the coil over multiple scalp positions on both hemispheres using suprathreshold stimulus intensities. For each hemisphere, the site evoking the largest MEPs was subsequently marked on the scalp. A series of cortical stimulations over this site was then performed, starting at subthreshold intensity and increasing by 5% increments of stimulator output until a motor threshold (MT) intensity was found. MT was defined as the minimum intensity of stimulator output required to evoke MEPs of 20 μV on at least 5 of 10 consecutive trials. For each participant, the hemisphere that presented the lower MT was chosen for stimulation. Following determination of MT and testing side, two blocks of 20 MEPs (B1, B2) using a test stimulus (TS) intensity of 120% of MT were recorded. The stimuli were delivered with a 5-s interval between each stimulus. After the intervention, further blocks of 20 MEPs were recorded immediately and every 5min for 15 min following thermal stimulation

(P0, P5, P10, P15). Each participant underwent the three different thermal stimulations on separate sessions in a randomized order. Intersession intervals were at least 24 h.

Statistical analyses

Comparability of the three intervention groups with respect to RMT and test MEP size at baseline was established using the Kruskal-Wallis test.The Greenhouse-Geisser correction was used if necessary to correct non-sphericity. A repeated-measures ANOVA using raw MEP values was performed with factors INTERVENTION (Ice to mouth, Ice to neck and No ice) and TIME (P0, P5, P10 and P15). For each thermal stimulation condition, a one-way ANOVA using raw MEP values with the factor TIME (Baseline, P0, P5, P10 and P15) was computed to assess changes over time. Paired t-tests were used in the post hoc analysis. ~~Bonferonni correction was used for multiple comparisons.~~ For baseline measurements data were reported as the mean value ± standard error (SE). Data were analyzed using SPSS-software (SPSS ver. 23.0 for Windows; SPSS Inc.).

Results

Baseline physiological measurements are shown in Table 1 and did not differ significantly between intervention types.

Figure 1 shows the time course of each intervention types. There was a siginifcant INTERVENTION x TIME intercation ($F_{8,84}$=3.76, p<0.01; two way repeated-measure ANOVA), indicating that there was a difference between the effect of the three types of intervention on corticobulbar excitability. One-way ANOVAs showed that only the Ice to mouth intervention produced a significant effect on the time course of corticobulbar excitability ($F_{4,28}$=4.04, p=0.01). Post hoc paired t-tests showed that there were significant differences between excitability at baseline and at P0 (p<0.05), P5(p<0.01) and P10 (p<0.01). In contrast, ice to the neck and no ice failed to influence MEPs ($F_{4,28}$=1.13, p=0.36; $F_{4,28}$=1.36 p=0.27, respectively). When the raw data were normalized to baseline to allow for comparisons between the post-session effect, the post hoc paired t-tests showed that the main differences between 'Ice to mouth' and the other two interventions occurred at P0 (p<0.05), P5(p<0.01) and P10 (p<0.01).

Discussion

This is the first study to report the effects of ice stimulation of the oral cavity on the excitability of the human cortical swallowing motor pathway. Ice in the mouth but not ice on the neck or no ice increased excitability of the corticobulbar projection to myohyoid muscles for at least 10min after application.

Several previous studies have reported that triggering of the pharyngeal phase of swallowing is shortened by cold stimulation in nondisabled subjects and dysphagic patients [15] [16] [17]. In general, when the larynx and pharynx are stimulated,

pharyngeal and laryngeal sensory receptors transform the cool sensations into signals to initiate the swallowing response. The base of the tongue, posterior pharyngeal wall, anterior faucial arches, epiglottis, and arytenoids appear to be especially sensitive in the swallow reflex. The signals are transmitted through the superior laryngeal nerve and the pharyngeal branch of the glossopharyngeal nerve. The superior laryngeal nerve, a branch of the vagus nerve, is the main laryngeal afferent peripheral nerve, and and the pharyngeal branch of the glossopharyngeal nerve is the main pharyngeal afferent peripheral nerve. The signals are transmitted to the nucleus of the solitary tract and then to the swallow center in the medullary reticular formation. Thus, it is suggested that ice stimulation into mouth facilitated the motor cortex excitability through this pathway.

This reasoning would be consistent with the fact that ice stimulation applied to the neck or room temperature stimulation into mouth had no effect. Note that all three types of stimulation involved repeated volitional swallows. Thus we can conclude that these swallows alone had no effect on corticobulbar excitability. Similarly, Al-Toubi and colleagues reported that repetitive volitional swallowing showed no significant effect on MEP.

Overall, previous studies have mainly focused on the effect of ice on triggering swallows and shortening the duration of pharyngeal phase, but no study to date has focused on the changes in cortical swallowing motor pathway excitability. Our results suggest that in addition to immediate effects on swallowing excitability, ice in the oral cavity leads to lasting changes in corticosbulbar excitability that persist for at least 10 min. Thus ice stimulation could be used as a pre-conditioning for swallowing rehabilitation.

Conclusions

We found that ice stimulation of the oral cavity increased the excitability of the human cortical swallowing pathway. Further studies of swallowing patterns in patients with dysphagia could incorporate similar forms of stimulation into current training protocols.

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Disclosure Statement:

All authors declare no conflicts of interest.

Table 1. Baseline physiological measurements

	Ice touch to inside mouth	Ice touch to neck	Normal temperature touch to inside mouth	P values
RMT	57.4 (9.4)	55.8 (9.7)	57.5 (10.7)	0.85
Test MEP (mV)	0.12 (0.05)	0.12 (0.06)	0.13 (0.06)	0.65

Figure 1 Legend

Group data showing effects of each intervention on mean MEP amplitude and there was an significant effect of time on raw MEP for only Ice to mouth, ($F_{8,84}=3.76$, $p<0.01$; two way repeated-measure ANOVA). Post hoc paired t-tests showed that there were significant differences between excitability at baseline and at P0 ($p<0.05$), P5($p<0.01$) and P10 ($p<0.01$) after Ice to mouth.

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