Dysphagia 11:198–206 (1996)

Dysphagia

The Effects of Cold, Touch, and Chemical Stimulation of the Anterior Faucial Pillar on Human Swallowing

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Abstract. Cold stimulation of the oropharyngeal mucosa, including the faucial pillar region, is used as a specific technique for the treatment of swallowing disorders. The physiological mechanisms underpinning this clinical technique are unclear. Thermal (cold), chemical (saline, glucose and water), mechanical (light touch) and feigned stimulation of the faucial pillar were assessed for their effects on the latency to swallow and the repetitive frequency of swallowing. There was no significant difference between these variables following light stimulation of the faucial pillar with a metal probe warmed to body temperature compared with feigned stimulation. However, cold touch stimulation evoked a significant increase in swallowing latency and repetitive frequency compared to feigned stimulation. The results suggest the existence of thermo-sensitive receptors in the faucial pillars that evoke swallowing when stimulated by cold touch. The clinical and physiological importance of these findings are discussed.

Key words: Faucial pillar — Thermal stimulation — Cold, touch, taste — Laryngograph — Deglutition — Deglutition disorders.

Dysphagia or the inability to swallow, is a debilitating disorder with any number of etiologies. It has been suggested that patients who have a severely impaired swallow may benefit from a therapeutic technique known as thermal stimulation [1], a technique that is in widespread clinical use. The procedure involves a brief, light touch with a cooled laryngeal mirror to the faucial pillar followed by the application of small amounts of iced fluid. The clinical acceptance of this technique suggests that the sensitivity of the faucial pillar can be enhanced by cold and/or touch stimulation which in some manner facilitates swallowing.

Only two studies have attempted to evaluate the efficacy of cold stimulation as a treatment for dysphagia. Lazzara et al. [2] reported that cold stimulation improved the triggering of the swallow in 23/25 neurologically impaired patients, however, the long-term effects were unclear. Rosenbek et al. [3] also observed that application of cold touch had an immediate effect on swallowing, but concluded that there was insufficient evidence to support or refute the efficacy of cold stimulation as a therapeutic procedure. More recently, the nature of cold stimulation of the faucial pillar as the effective stimulus has been questioned [4]. Chi-Fishman et al. [5] found that in an experimental animal preparation, stimulation of the mucosa (32.7°C–35.5°C) with a metal probe either several degrees cooler (25.3°C) or much colder (8.9°C) than the mucosa increased the number of swallows that could be evoked by electrical stimulation of the internal laryngeal nerve.

The physiological mechanism(s) underlying cold stimulation as a procedure to evoke swallowing has not been systematically investigated. The soft palate, pharyngeal surface of the epiglottis, glossoepiglottidinal sinus, posterior wall of the pharynx, and the pharyngo-esophageal junction have all been identified as potential sites from which swallowing can be evoked [6–8]. Of these, the faucial pillars have been identified as the site from which swallowing is most consistently elicited in the human oropharynx [8,9]. The mucosa contains taste buds [10] and it is also possible that the stimulation of taste receptors is important in evoking swallowing responses in natural situations.

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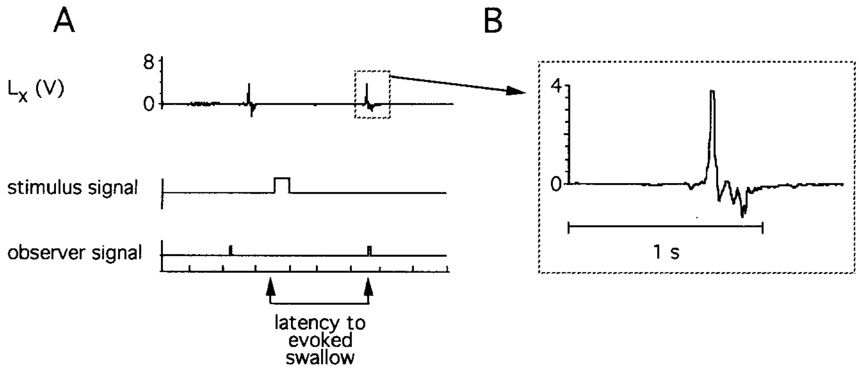

Fig. 1. Laryngograph (L_x), stimulus and observer signals recorded from 1 subject (see text). The observer signals in anticipation of the L_x signal for the first swallow, and at about the same time as the second swallow. The part of the L_x waveform enclosed by the box in **(A)** is enlarged in **(B).**

In the present study, the faucial pillar was selected as a site to study the effects of touch, cold, and chemical (taste solutions and water) stimulation on swallowing in healthy young women. Stimuli included light touch with a warmed and cooled laryngeal mirror as well as infusions of warm and cooled solutions of saline, glucose, and distilled water.

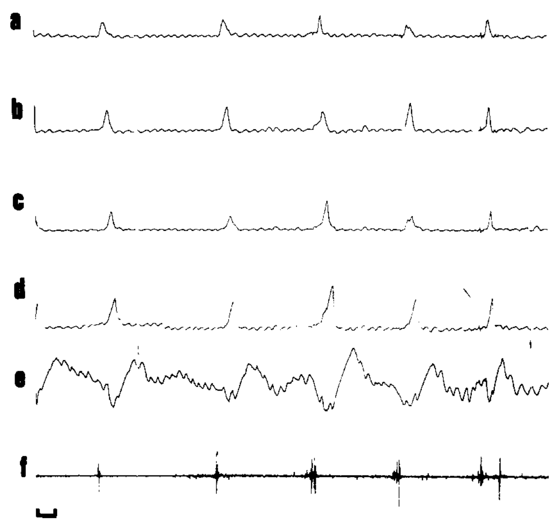

Fig. 2. Trace recordings comparing laryngograph (L_x) waveforms with those of a water-perfused manometer inserted into the esophagus of one of the subjects. Traces **(a–d)** illustrate the sequential contractions in the esophagus during swallowing. Trace **(e)** is located at the level of the lower esophageal sphincter; the oscillation of this signal is probably related to respiration. The L_x signal is shown in trace **(f).** The sequence of events begins with the swallow shown on trace **(f)** and is followed by the sequential peristalsis down the esophagus ending with the relaxation of the lower esophageal sphincter. Each swallow shown by a deflection of the L_x waveform is followed by a peristaltic wave recorded by the manometer. Some of these swallows show single deflections of the L_x signal; others show multiple deflections.

Subjects and Methods

Ten female subjects between the ages of 21 and 37 years (mean 26.3 years), volunteered to participate in the study which was approved by the institutional ethics committee. The subjects reported that they were in good health, did not smoke and were not on any medication. They were instructed not to drink any beverages containing caffeine, or to eat spicy food 12 h prior to the study in order to minimize obvious chemical influences on the oropharyngeal mucosa. The specific aims of the study were not disclosed until after the completion of data collection.

Each subject was seated in a high-backed, padded armchair so that her head was maintained comfortably in a vertical position without obvious flexion or extension. Speech was discouraged once the protocol had commenced. Prior to the commencement of each of the various tests the subject was asked to open her mouth.

Identification of Swallowing

A Kay laryngograph (L_x) was used to provide a clear signal for the detection of the onset of swallowing via electrodes placed on each side of the subject's thyroid cartilage with a velcro strap [11,12]. Two additional female subjects undergoing routine investigation for gastroesophageal reflux were studied by simultaneous recordings of the L_x and pharyngoesophageal pressure signals [13]. A water-perfused manometer (O.D. 0.5 cm) with a 6 cm sleeve assembly was introduced into the subject's pharynx via the nose by a gastroenterologist following topical anaesthesia of the nostril (Xylocaine 10% spray, Astra Pharmaceuticals, Pty Ltd, North Ryde, Australia). The perfusion system was a standard Arndorfer chamber, pressurized with compressed nitrogen. Figure 1 depicts 5 L_x waveform deflections coinciding with episodes of swallowing, each of which are followed by a peristaltic wave recorded as sequential esophageal contractions (Fig. 1 a-d) and a pressure change at the site of the lower esophageal sphincter (LES) (Fig. 1e). Note that the onset of the L_x signal occurs 250 ms prior to the first contraction in the upper esophagus, reflecting peristalsis and the relaxation of the LES.

Swallowing was always associated with a L_x signal deflection, but it was also observed that head, neck, and tongue movements unassociated with swallowing (not illustrated) produced similar signals on the L_x. For this reason, an independent observer, seated to that the subject's neck was in profile, pressed a button when she observed a swallow (observer signal). The co-occurrence of a L_x deflection and an observer signal was considered to represent a swallow.

The investigator was positioned directly in front of the subject and a head mirror and light were used to illuminate the subject's oropharynx to facilitate application of the stimulus to the same part of the faucial pillar in the various tests. The investigator pressed a button (stimulus signal) at the onset of the application of the stimulus to the faucial pillar. An example of the three signals is shown in Figure 2. In this figure, the L_x signal (uppermost trace) shows a deflection prior to the application of the stimulus (warmed fluid), presumably representing a spontaneous swallow, and a second deflection is apparent following the stimulus, presumably representing the evoked swallow.

Experimental Protocol

The study consisted of seven experimental conditions in which various fluid and touch stimuli were administered to each subject's left faucial pillar. The chemicals included taste solutions isotonic saline (0.154 M) and glucose (0.5 M) as well as distilled water which were each infused for 3 sec through a 1.2 mm diameter intraoral tube by a pump at a rate of 0.1 ml/sec. A low, constant flow rate was selected to minimize the mechanical effect of the stimulus. A 00 size laryngeal mirror was used to touch the faucial pillar. Tests were conducted at 3-min intervals to prevent adaptation effects. For the different subjects, the order of the experimental conditions was randomly ordered.

Condition 1. A laryngeal mirror warmed to body temperature (37.5 ± 1°C) was used to provide a single, light touch for a period of 5 sec. Five separate tests were administered.

Condition 2. Same as for condition 1 but the laryngeal mirror was cooled in ice (0 ± 1°C). This condition replicated the clinical protocol for thermal stimulation [1-2].

Condition 3. A laryngeal mirror was advanced to the faucial pillar but no contact was made, and contact was feigned. The feigned stimulus sought to establish whether a time effect, anticipation, or the action of the subject opening her mouth could account for any of the observed responses.

Condition 4. Same as for condition 1 except that three light touches from the top to the base of the faucial pillar were applied to the faucial pillar.

Condition 5. Same as for condition 4, but the laryngeal mirror had been cooled in ice (0 ± 1°C) for several minutes prior to use.

Condition 6. Five tests of water, 5 tests of glucose, and 10 tests of saline, each warmed to body temperature (37.5 ± 1°C) were applied. The order of the water and glucose was varied between subjects, and for each subject, a saline condition was interspersed between glucose and water conditions. The solutions were warmed by an immersion heater and temperatures were monitored with a thermometer. Following infusion onto the faucial pillar, the small quantity of applied solution (approximately 0.3 ml) dribbled onto the posterior part of the tongue.

Condition 7. Same as for condition 6, but the chemicals were cooled (6 ± 1°C) by placing the solutions on a bed of ice. This condition replicated, in part, the clinical practice advocated by Logemann et al. [1,2] who recommend applying cooled fluids following sensitization of the faucial pillars by cold touch stimulation.

Data Collection and Analysis

The data were stored and also displayed on-line using a Macintosh SE computer running Mac Lab software (ADInstruments, Castle Hill, Australia). Swallowing was observed 30 sec prior to and following the application of each stimulus, and evoked swallows were defined as those that occurred within this time period following the stimulus application. Two variables were measured within the 30-sec sampling period following the stimulus: the latency to swallow and the number of swallows evoked. Additionally, the percentage of tests in which swallowing was successfully evoked for each condition and subject was determined. The method used to measure the latency to swallow is shown in Figure 2 as the time between the stimulus signal and the L_x peak corresponding to the first swallow. In order to be able to classify nil responses, latency data were arbitrarily divided into speed of response. A *brisk* response was defined as a response occurring within 15 sec of stimulation. Swallowing that occurred between 15 and 30 sec of stimulation was deemed to be a *response,* whereas a failure to swallow within 30 sec after stimulation was classified as *no response.*

Two by three Chi-square comparisons between the latency responses to each of the stimuli and feigned stimulation were made. Grouped data for number of swallows and percentage of successful swallowing tests were expressed as means ± standard error. Other statistical comparisons were carried out using one- and two-way analyses of variance (ANOVA). Where the overall analysis was significant, the differences between the means were detected by post hoc testing using the Schéffe procedure. A probability of 5% was considered significant in all tests.

Table 1. Frequency distribution of latency responses for the subjects following single and repetitive stimulation of the faucial pillar with a laryngeal mirror warmed to body temperature

Touch stimulation mode	Brisk response (<15 sec)	Response (15–30 sec)	No response (>30 sec)
Single	30% (12)	(20% (8)	50% (20)
Repetitive	20% (10)	18% (9)	62% (31)

The percentage of tests for each of the three conditions is shown, and in parentheses, the number of responses.

Results

Feigned Stimulation

Comparison of the number of spontaneous swallows within the 30-sec period prior to each of the feigned stimulation tests revealed that the number of spontaneous swallows (mean 0.46 ± 0.06) was not significantly different from that which occurred during a similar period following feigned stimulation (mean 0.37 ± 0.06; one-way ANOVA, F[178] 1.03, $p > 0.05$). Similar results were obtained for a comparison for the percentage of tests in which swallowing occurred spontaneously within a 30-sec period prior to stimulation (41.11% ± 7.83) with that in a similar period following feigned stimulation (30 ± 7.28%, one-way ANOVA, F[34] 1.08, $p > 0.05$). Accordingly, the feigned stimulation test was used as a control condition for the remaining data analyses.

Touch Stimulation

Comparison of single and repetitive touch stimulation for the faucial pillar with a warm laryngeal mirror (37°C) on 8 of the 10 subjects who were tested with both modes of stimuli revealed no significant difference with respect to latency to swallow (Chi-square, $p > 0.05$, Table 1). Further, there was no significant different between the

Table 2. Frequency distribution of latency responses to warm and cold touch and feigned stimulation

Touch condition	Brisk response	Response	No response
Feigned	18.88% (17)	11.11% (10)	70.00% (63)
Warm (37°C)[b]	24.44% (22)	18.89% (17)	56.67% (51)
Cold (0°C)[a,b]	40% (36)	25.56% (23)	34.44% (31)

Brisk (<15 sec), response (15–30 sec), and no response (no swallow occurred within 30 sec). Other conditions as per Table 1.
[a]Feigned.
[b]$p < 0.05$.

number of swallows evoked within 30 sec (mean 0.55 ± 0.09 single, 0.40 ± 0.08 repetitive; one-way ANOVA, F[88] 1.58) or the mean percentage of successful swallowing tests (50 ± 10.69% single, 38 ± 10.52% repetitive; one-way ANOVA, F[16] 0.63, $p > 0.05$). Accordingly, data for single and repetitive touch stimulation were combined for the remaining analyses for these 8 subjects.

Touch stimulation with a laryngeal mirror warmed to body temperature evoked brisk responses in 24.44% of tests compared with feigned stimulation which evoked a brisk response in 18.88% tests; these comparisons were not significantly different (Chi-square, $p > 0.05$, Table 2). In both cases there was also a high percentage of tests in which no response was evoked (56.67% and 70%, respectively). Additionally, there was no significant difference between the number of swallows evoked following warm touch stimulation (mean 0.47 ± 0.06) and feigned stimulation (0.37 ± 0.06; one-way ANOVA, F[178] 1.35, $p > 0.05$). Similar results were obtained for the mean percentage of successful swallowing tests (mean 43.33 ± 7.45% and 30.0 ± 7.28%, respectively; F[34] 1.64, $p > 0.05$).

Cold Touch Stimulation

Cold touch stimulation evoked a significantly higher percentage of brisk swallowing responses (40%) compared with feigned stimulation (18.8%; Chi-square, $p < 0.05$, Table 2). There was also a significant difference between the number of swallows evoked following cold touch stimulation (mean 0.79 ± 0.07) and feigned stimulation (mean 0.37 ± 0.06; one-way ANOVA, F[178] 20.43, $p < 0.001$). Similar results were obtained for the mean percentage of successful swallowing tests (mean 65.56 ± 7.89% vs. 30.0 ± 7.28%, respectively; F[34] 10.98, $p < 0.01$).

Cold touch stimulation evoked a significantly greater number of brisk responses compared with warm touch (Chi-square, $p > 0.05$, Table 2). There was a significant difference between the number of swallows following warm touch (0.47 ± 0.06) and cold touch (0.79 ± 0.07, $p < 0.001$; one-way ANOVA, F[178] 12.34. Cold touch also evoked a significantly greater number of successful swallowing trials (65.56 ± 7.89%) than warm touch (43.33 ± 7.45%, $p < 0.05$; one-way ANOVA, F [34] 4.19).

Table 3. Frequency distribution of latency responses to chemical stimulation of the faucial pillar by infusions of 0.5 M glucose, isotonic saline (0.154 M), or distilled water

Stimulation condition	Brisk response	Response	No response
Warm chemicals (grouped) (37°C)[a]	64.5% (129)	18% (36)	17.5% (35)
Cold chemicals (grouped) (6°C)	56% (112)	18.5% (37)	25.5% (51)
Warm glucose (37°C, 0.5 M)	56% (28)	24% (12)	20% (10)
Cold glucose (6°C, 0.5 M)	60% (30)	22% (11)	18% (9)
Warm isotonic saline (37°C, 0.154 M)	73% (73)	14% (14)	13% (13)
Cold isotonic saline (6°C, 0.154 M)	63% (63)	13% (13)	24% (24)
Warm distilled water (37°C)	56% (28)	20% (10)	24% (12)
Cold distilled water (0°C)	38% (19)	26% (13)	36% (18)
Feigned[a]	17% (17)	10% (10)	73% (73)

Warm or cold chemicals refers to the response to the three chemicals as a group. Other conditions as per Tables 1, 2.
[a]$p < 0.05$.

Chemical/Tactile Stimulation

The application of various fluids (warmed glucose (0.5 M), isotonic saline (0.154 M), and distilled water solutions) potentially constituted a combined chemical and tactile stimulus. These tests resulted in a large number of brisk swallowing responses (64.5% of the tests on 10 subjects; Table 3) and only 17.5% of tests failed to elicit any swallowing response within 30 sec. However, there were no significant differences among the three chemicals with respect to the latency of the elicited swallows (Chi-square, $p > 0.05$; Table 3). As a group, the three chemicals were each significantly different to feigned stimulation (Chi-square, $p < 0.05$; Table 3).

The number of swallows elicited and the percentage of successful swallowing tests recorded in response to the three chemicals each were significantly different to the feigned stimulation condition (number of swallows—glucose 1.0 ± 0.09, saline 1.24 ± 0.07, water 0.94 ± 0.09, feigned 0.33 ± 0.06, one-way ANOVA, F[296] 35.65, $p < 0.0001$; percentage of successful swallowing tests—glucose 80 ± 5.97%, saline 87 ± 6.16%, water 76 ± 10.24%, feigned 30 ± 7/28, one-way ANOVA, F[44] 13.60; $p < 0.0001$). Comparisons among each of the three chemicals indicated that saline elicited a significantly greater number of swallows (mean 1.24 ± 0.07) compared with water (mean 0.94 ± 0.09) (one-way ANOVA, F[197] 4.13; $p < 0.001$). There were no significant differences with respect to the percentage of successful swallowing tests for each of the three chemicals. Several subjects spontaneously commented on the taste of the saline and the glucose during the procedure.

Chemical/Tactile/Cold Stimulation of the Faucial Pillar

There was no significant difference among the latency to swallow following applications of glucose, saline, or water at either body temperature or cold (comparison of warm and cold chemicals; Table 3; Chi-square, $p > 0.05$). However, applications of the warm chemicals evoked a slightly greater number of swallows (mean 1.11 ± 0.05) than cold chemicals (mean 0.93 ± 0.05, two-way ANOVA, F[2] 6.17 $p < 0.01$). There was no interaction among the specific chemicals and the warn/cold condition (F[2] 1.5). There was also no significant difference between the percentage of successful swallowing tests evoked after applications of either warm chemicals (81% ± 4.38) or cold chemicals (74% ± 5.07, one-way ANOVA, F[2] 0.45, $p > 0.05$).

Intersubject Variability

Intersubject variability was observed for the number of swallows elicited in response to the various conditions (two-way ANOVA, F[9] 8.00 $p < 0.0001$) but there was not interaction between the subjects and the conditions (F[27] 1.09). There were no significant intersubject differences among the percentage of successful swallowing tests over the same four conditions (two-way ANOVA, F[9] 3.05 $p > 0.05$).

Discussion

Cold Touch Stimulation of the Faucial Pillars

One of the significant and novel findings of this study was that cold touch to the faucial pillars significantly affected swallowing behavior. This finding may serve, in part, to explain the success that has been reported in treating swallowing disorders by cold stimulation [2].

There are several reasons to support the idea that the swallowing responses following cold touch stimulation are mediated by thermosensitive receptors in the faucial pillar as there was a significant increase in swallowing *only when the laryngeal mirror probe was cooled.* This finding suggests that the cooling of the mucosa by the cold laryngeal mirror rather than the mechanical stimulation was the crucial feature of the stimulus. It is also important to note that the responses to cold touch were not associated with opening the mouth or the introduction of a laryngeal mirror, as there was no significant change in swallowing behavior following feigned stimulation. These data support the idea that the human faucial pillar contains cold-sensitive receptors, which, when stimulated by a light touch with a cooled laryngeal mirror, increase swallowing latency and repetitive frequency.

Sensory information from the numerous receptors innervating the human oral cavity and pharynx is mediated by the trigeminal, facial, glossopharyngeal, and vagus nerves and the density of receptors decreases from the anterior to posterior regions of the oral cavity [14]. There are few histological reports of the sensory innervation of the faucial pillars, although this region is known to mediate the sensations of touch, temperature, and pain [15,16]. Studies of the mucosa in the lateral region of the palatopharyngeal arch have identified encapsulated and nonencapsulated nerve endings [17] as well as numerous taste buds [10].

An explanation for the observed enhancement of the swallowing response by cold is that the faucial pillars contain cold-sensitive receptors and that these were stimulated by the cold laryngeal mirror and evoked swallowing. Discrete cold receptors have not been identified histologically in oropharyngeal, nasal, or laryngeal mucosa, although they have been described physiologically. Single fibers sensitive specifically to cooling of the tongue [18], the larynx [19], and the nasopharynx [20] have been isolated. There is also functional evidence for the existence of cold receptors in the oropharynx. In studies examining the sensation of thirst, the secretion of vasopressin by the hypothalamus has been shown to be a critical factor. It has been shown that ice chips in the oropharynx, but not a similar volume of cool (17.5°C) or warm water (25°C), decreased blood levels of vasopressin in dehydrated human subjects [21]. These data may explain the preference for iced water frequently exhibited by dehydrated human and experimental animal subjects [22,23].

The temperature range associated with laryngeal cold receptor excitation appears to be between 20°C and 34.5°C [24] although nasopharyngeal receptors responding to temperatures below 15°C have also been described [20]. It has been reported that the highest temperature that humans first recognize cold stimulation on the anterior faucial pillar is when a metal probe at 33.5°–36°C is touched to the mucosa [15]. We used a metal probe cooled in ice in line with clinical protocols [1,2], and although we did not measure the mucosal temperature change or the rate of temperature change induced by our stimuli, previous studies have shown that applications of cool saline (13°C) to the laryngeal mucosa resulted in changes in mucosal temperature of only a few degrees (decrease of 35.2°C to 32.4°C), presumably because of the vascular perfusion of the mucosa [25]. Therefore, it is possible that the mucosal temperature decrease induced by our iced probe stimulation may not have exceeded 20–34.5°C, i.e., within the range in which cold receptors are sensitive. This is also consistent with the finding of Selinger et al. [4] that the temperature of a cooled probe warmed rapidly when it was removed from a beaker of ice and was placed on the faucial pillar. The initial mucosal temperature should have been constant for each test, since we allowed 3 min between the application of each stimulus [26].

Another possibility is that the cold stimulation was a nociceptive stimulus. The latter refers to a type of afferent stimulation likely to cause tissue damage and transmitted by small C-fiber axons. It has been proposed, in a study on cold, touch, and taste sensitivity of the tongue, that cold solutions (at 5°C) could activate nociceptors [27]. Swallowing as a reflex response to nociceptive stimulation of the oropharynx is one method of removing the stimulus from the region and may have functional significance. This possibility may explain why we have been able to show that cold touch had a significant effect on swallowing behavior, whereas other studies which have not used an iced probe have failed to show a significant cold effect.

Cold stimulation is generally inhibitory to mechanoreceptors, including oropharyngeal mechanoreceptors [28]. A third possibility for the present results is suggested by the findings of Hensel and Zotterman [29] who described a small group of mechanoreceptor fibers in the cat lingual nerve that responded to pressure as well as cooling. However, these mechanoreceptors only responded to very low temperatures and to rapid cooling, whereas specific cold receptors in the same nerve displayed an exquisite sensitivity to cooling, and could signal changes in temperature as small as a tenth of a degree. Also, the mechanoreceptor response to cooling disappeared after a few seconds, whereas the cold receptor continued responding as long as the constant low temperature was maintained. It is possible that cold stimulation by the laryngeal mirror probe activated faucial pillar mechanoreceptors, and that the touch stimulation was somehow intensified by the cold state of the probe. If so, it would be necessary to explain why touch stimulation by the cold probe was effective in changing swallowing behavior, but the infusion of cold chemicals onto the same mucosa area was not.

The application of cold solutions did not have much influence on swallowing behavior, whereas the cold touch evoked more rapid swallowing. Although the cold mirror was at 0°C and the cooled fluids at 6°C, both stimuli would be likely to have provoked a sufficient drop in temperature to activate cold receptors. Since the mirror would have contacted only a discrete site (6 mm diameter), the force per unit area may have been greater on a smaller number of receptors than with the more diffuse stimulation when the fluids flowed over the faucial pillar.

It is known that a swallow will not be initiated without productive lingual movement. An alternative possibility is that the cold touch stimulus evoked tongue movement which facilitated the swallow response. That the cold solutions had much less influence argues against this possibility.

Touch Stimulation of the Faucial Pillar

Pommerenke [8] found that mechanical probing of the human faucial pillars evoked swallowing. This study failed to confirm that swallowing could be evoked by touch stimulation of this region *when the latter was provided by a probe warmed to body temperature.* Pommerenke did not describe the temperature condition of the glass stimulating probe, but if used at room temperatures, it is possible that it transmitted a degree of cooling to the faucial pillar mucosa.

Alternatively, it is possible that this difference is related to variation in the mechanical stimulus. Recently, it has been shown that mechanical tapping of the faucial pillar in human subjects continuously for over 1 min with a plastic rod evokes the desire to swallow in some subjects [30]. Sinclair [31] evoked swallowing in experimental animals by touching the faucial pillar with wooden applicators (1-6 mm in diameter) and found that heavy and light stimulation of the posterior faucial pillars evoked similar responses, leading him to conclude that the receptors responsible for initiating swallowing were superficially located. It is difficult to relate these data to the findings of the present study involving a different species, and different applicators and variation in the amount of mechanical pressure.

The initial description of the cold stimulation technique involved a light touch to a faucial pillar [1]. In a later publication [32], the stimulus was described as being a stroke of 0.75–1.0 sec duration. The latter stimulus introduces another aspect, a vibrotactile form of stimulation, as opposed to a single light touch or indentation of the mucosa. In the present study, the results obtained following stimulation of a single discrete area on the faucial pillar were not different from the results from multiple light touches moving progressively down the faucial pillar. The area that was stimulated by the laryngeal mirror was uniform for the various single touch stimulation tests but clearly was different when we applied multiple touch stimulation and fluids. Nevertheless, as no apparent differences were found for single and multiple touch stimulation, the density of receptors present in the area was apparently not an important factor in the evoked response studied.

Chemical Stimulation of the Faucial Pillars

There were no significant differences among 0.5 M glucose, isotonic saline, and distilled water with respect to the latency of evoked swallowing when these solutions were applied at body temperature. Saline was slightly more effective than distilled water in the number of swallows evoked, but the change was very small. In contrast, there was a large difference in the swallowing behavior induced by all three chemicals compared with feigned stimulation. The present data cannot offer an explanation for this, but as the small quantity of infused chemical (0.3 ml) trickled down onto the posterior tongue and pharyngeal area, it may have stimulated receptors in other sites. The uniformity of the response to the different chemicals argues for a mechanical "flow" effect either from receptors in the faucial pillar or associated with the movement of the fluid into the oropharynx. Water is the most effective stimulus with which to evoke swallowing from the larynx [33–35]. The present data indicate that water is no more effective than saline or glucose on the faucial pillar.

Taste receptors appeared to be stimulated by our tests as most subjects spontaneously commented on a salty taste with applications of saline and to a lesser extent, a sweet taste with glucose application. Although the taste threshold is lower on the tongue, sweet and salty substances have been previously reported to be perceived on the palatal area [36–38]. Possibly the small differences we observed with saline stimulation described above were due to the activation of taste receptors. As well as the faucial pillar tissue [10], other sites within the oropharynx also need to be considered as putative receptive field sites for the chemical (fluid) data. Although temperature has been shown to interact with taste in altering taste threshold in the oral cavity [38,39], we did not find any differences between the warm and cold chemical solutions.

Variation of Subjects' Responses

The subjects varied in their responses, as previously observed [8,30]. There are several factors that may explain these variations such as the subjects' physical characteristics, the effects of jaw opening, or the sensitivity of the faucial pillars. Individual variations in the length and mass of the faucial pillars of each subject were observed during the stimulus application. The extent to which the jaw was opened during the application of the stimulus appeared to affect the prominence of the faucial pillars, and hence the amount of visible surface area. Whether these physical features might relate to differences in sensitivity to touch or receptor density and distribution is not known.

Clinical Implications

The main aim of this study was to determine whether chemical (taste), touch, and/or cold stimulation of the anterior faucial pillars affected swallowing behavior. Under the conditions of the present study, it was clear that cold touch stimulation of the faucial pillar was effective. This result has important clinical ramifications.

The use of cold in the form of ice chips placed in the mouth, on the neck, or on the face are considered to influence swallowing. The use of cold fluids and the avoidance of tepid fluids have also been suggested in numerous papers on swallowing management [1,40–45]. Dysphagic patients will often comment that they find cold fluids easier to swallow and that they are less inclined to aspirate cold fluids (Kaatzke-McDonald, unpublished observations).

Is it possible that a response to cold receptors provides the physiological basis of these clinical observations? The results of this study offer specific evidence for the existence of cold-sensitive receptors in the faucial pillars and supports the therapeutic use of cold stimulation in dysphagia management. These results are particularly significant given that in spite of the variability between subjects, the response to cold touch was consistent. Our data indicate that the application of small quantities (0.3 ml) of cool fluids such as saline glucose or water may be less effective than using a cold laryngeal mirror. However, our data applies specifically to the faucial pillar area and it may be that cold fluids in greater quantities are more effective.

The use of cold or cryotherapy as a therapeutic technique is found in much of the physiotherapy literature. Cryotherapy has been used therapeutically for the treatment of various neurological and muscular conditions [46–50]. There is clinical evidence that the stimulation of cutaneous receptors by cold leads to the activation of muscles in the region stimulated, however, the physiological mechanism underlying these observations is not understood. An early hypothesis was that the cold stimulus causes activation of the gamma efferent fibers innervating muscle spindles within the stimulated region, leading to contraction of the intrafusal muscle fibers and a reflex increase in muscle tone [51]. Although muscle spindles have been identified in the human palatoglossus muscle of which the anterior faucial pillar is a part [52], there is no evidence to support or reject this proposal.

Clinical measurement of swallowing behavior is facilitated by the noninvasive use of the laryngograph [11,12,53,54]. Perlman and Grayhack [12] reported that the laryngograph waveform was associated with hyoid movement during swallowing and concluded that it provided a reliable tool for measuring low-frequency changes in impedance during swallowing. However, it should be noted by clinicians that we observed that head and neck movement unassociated with swallowing produced laryngograph signal deflections similar to those that occurred during swallowing. Certainly the laryngograph indicated the timing of the swallowing movements more reliably than could possibly be provided by the observer, and when used in this manner we concur that the laryngograph provides a reliable measure of swallowing.

The results of this study provide insight into the physiology of the faucial pillars and offers specific evidence for the existence of cold-sensitive receptors in this region. It provides a possible explanation for the anecdotal and clinical experience that cold touch to the faucial pillars can significantly improve swallowing under certain conditions [55] and supports the basic premise of cold stimulation [1,2]. For clinicians, it clearly demonstrates a physiological rationale for the use of cold stimulation in the management of dysphagic patients although the choice to use cold stimulation must be evaluated in the context of the underlying etiology of the swallowing impairment. Further investigation is needed to evaluate the potential effects of neurological disease and aging on these effects.

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