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Influence of Cold Stimulation on the Normal Pharyngeal Swallow Response

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Abstract. We examined the potential influence of cold stimulation of the anterior tonsillar pillars, before and after topical anesthesia, on the temporal linkage between the oral and pharyngeal components of the swallow. We hypothesized that if elicitation of the pharyngeal swallow were dependent upon stimulation of faucial mucosal receptors this response would be facilitated by cold tactile stimulation and inhibited by topical anesthesia. In 14 healthy volunteers undergoing simultaneous videoradiography and manometry we measured and compared regional transit and clearance times, and the timing of hyoid motion, upper esophageal sphincter relaxation, and opening within the swallow sequence. There was a significant, volume-dependent forward shift in timings of hyoid motion, upper esophageal sphincter (UES) relaxation profile, and opening which were influenced neither by cold stimulation nor topical anesthesia. Regional transit and clearance times and UES coordination were not influenced by cold stimulation. Pharyngeal clearance time was prolonged by tonsillar pillar anesthesia due to earlier arrival of the bolus head at this region ($p = 0.002$). We conclude that the normal pharyngeal swallow response is neither facilitated nor inhibited by prior cold tactile stimulation or topical anesthesia to the tonsillar pillars, respectively. These observations do not support the hypothesis that elicitation of the pharyngeal swallow response is dependent upon stimulation of mucosal receptors in the tonsillar arches.

Key words: Deglutition disorders — Deglutition — Mucosal receptors — Cold stimulation — Pharynx — Manometry — Radiology.

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It is not known whether the pharyngeal swallow response is actually a triggered response ("reflex chain" hypothesis) or whether the entire sequence, including the oral phase, is programmed as a unit by the medullary swallow center [1]. The pharyngeal swallow response is believed to be initiated by stimulation of pharyngeal receptors in the region of the anterior tonsillar pillars by the advancing bolus and the tongue via interneurons within the medullary swallow center [1]. The anterior tonsillar pillar region has been proposed to be one of the most sensitive areas for triggering the pharyngeal swallow response [2] but stimulation of a wide range of regional receptors is capable of initiating the swallow response [3,4]. Afferent input from oral-pharyngeal sensory receptors is therefore likely to be important, not only in pharyngeal swallow initiation but possibly in regulating the temporal relationships among events during the swallow [5,6]

The sequence of motor events is not stereotyped and can be modified by alterations in the characteristics of the swallowed bolus such as volume or viscosity [7–9]. Neurologically impaired individuals demonstrate a delayed pharyngeal swallow response [10] which is facilitated by cold, tactile stimulation of the anterior tonsillar fauces possibly by upregulating mucosal thermal receptors [11]. These observations suggest that oropharyngeal sensory receptors may influence the medullary control of timing among swallow events and the linkage of oral and pharyngeal components of the swallow. Our aim in this study as to test the reflex chain hypothesis by examining the temporal linkage between the oral and pharyngeal components of the swallow by cold sensitization followed by mucosal blockade of the putative oral-pharyngeal receptive fields and to determine whether manipulation of faucial thermoreceptors influences the temporal relationships among swallow events. We hypothesized that cold tactile stimulation would facilitate, and topical anesthesia would retard the pharyngeal swallow response.

Methods

Subjects

We studied 14 healthy volunteers (age 40–74, mean 59 ± 11 years) recruited from the community by advertisement. All were carefully screened and none had swallowing difficulties, medical illnesses, or were taking any medication that could have affected swallow function. Ethical approval was granted by Southern Sydney Area Health Service Ethics Committee in 1991 and all subjects gave informed consent.

Videoradiography

Subjects were studied by a simultaneous combination of videoradiography and manometry as previously described [12,13]. Briefly, subjects were studied seated and images of barium swallows were recorded in the lateral projections using a 9″ Siemens image intensifier. Fluoroscopic images were recorded on videotape at 25 frames per sec by a VHS video recorder (Panasonic, AG6500, Osaka, Japan) for later analysis. The correction factor for magnification was determined prior to each study by placing two metallic markers set 3 cm apart in the field of the image intensifier, above the subject's head but in the plane of the upper esophageal sphincter (UES). Subjects swallowed in duplicate 2 and 20 ml of high density barium suspension (250% wt/vol) (E-Z-HD, E-Z EM Inc., Westbury, NY), delivered to the mouth by a syringe. Included in the field of view were the incisor teeth anteriorly, hard palate superiorly, cervical spine posteriorly, and proximal cervical esophagus inferiorly. To enhance the fluoroscopic image, by preventing flaring, the subject held a water-filled latex glove loosely against the skin under the chin. A purpose-built, video digital timer unit (Practel Sales International, Holden Hill, South Australia) imprinted simultaneously the elapsed time on the video images in hundredths of seconds and a signal on the pressure tracing each whole second, to give precise temporal correlation of video images with pressure.

Manometry

The manometry catheter incorporated three solid state transducers (Gaeltec, Dunvegan, Isle of Skye, Scotland) recording pharyngeal pressures, and a sleeve assembly (Dentsleeve, Belair, South Australia) measuring UES pressure. The solid state catheter (O.D. 2.3 mm) was inlaid into a 6 lumen silicon rubber perfused manometric catheter (I.D. each lumen, 0.51 mm, overall O.D. 6 mm). The sleeve assembly distal to the transducers had a 5 × 3 mm oval cross-section to maintain its anteroposterior orientation within the UES. The manometric assembly was passed transnasally and all transducers and the sleeve orientated posteriorly with the sleeve straddling the UES. The solid state transducers were spaced 3 cm apart with the middle transducer lying at the level of the valleculae in the midpharynx and the distal transducer lying at the upper margin of the sleeve in the distal pharynx, just proximal to the UES at the time of maximal ascent during swallowing. Four perfused sideholes spaced at 1.5 cm intervals in the pharynx with the distal sidehole located 3 cm distal to the proximal sleeve margin, that is in the midsleeve position, were used to position the sleeve such that its midpoint was in the center of the UES high pressure zone at rest. Only the distal two sideholes were perfused during formal swallow evaluation and aided in accurate localization of the UES on the sleeve. The sleeve assembly was perfused by a low compliance pneumohydraulic perfusion system at 0.6 ml/min. UES pressures were registered by external transducers (Spectramed Medical Products, Singapore), and all signals were amplified and digitized at 200 Hz by preamplifiers (Neomedix Systems, Sydney, Australia) and recorded on a Macintosh II computer (Apple, USA) using Gastromac software (Neomedix Systems, Sydney, Australia).

Experimental Protocol

Swallows in each subject were recorded sequentially under four experimental conditions in the following order: (1) control, (2) cold stimulation of the anterior tonsillar pillars, (3) topical anesthesia to anterior tonsillar pillars, (4) cold stimulation following topical anesthesia to anterior tonsillar pillars. Cold stimulation to the anterior tonsillar pillars was administered by lightly touching the area with the base of an iced, size 00 laryngeal mirror for a total duration of 5 sec as described previously [11,14]. Mucosal anesthesia to the anterior tonsillar pillars was achieved with topical 2% Xylocaine Viscous (Astra Pharmaceuticals, Sydney, Australia) using a cotton-tipped applicator. The adequacy of anesthesia was confirmed by the absence of touch sensation to light contact with a probe.

Data Analysis

The definitions of the timing of swallow events were referenced to the initial movement of the tongue tip against the posterior surface of the maxillary incisors indicating the onset of the oral phase of the swallow. Pharyngeal events were also referenced to the arrival of the bolus head at the posterior tonsillar pillar as this represents the onset of one of the presumptive stimuli that might initiate the pharyngeal swallow response. Oral transit time was defined radiologically as the time interval between the onset of the oral phase and the arrival of the bolus tail at the posterior tonsillar pillar. Pharyngeal transit time was the interval between the passage of the bolus tail at the posterior tonsillar pillar and UES closure. Pharyngeal clearance time was defined as the interval from the first entry of the bolus head into the pharynx at posterior tonsillar pillar until UES closure. UES opening, closure, and duration of UES flow were defined fluoroscopically [7]. UES relaxation onset was defined as the time point when the basal UES pressure began to fall abruptly. Maximum UES relaxation was defined as the point in time when the UES relaxation profile ceased to fall rapidly and levelled off. Because the proximal sleeve margin projects into the hypopharynx, the sleeve prematurely registers the apparent termination of UES relaxation [15]. Accordingly, UES relaxation termination was measured from the tracing recorded by the sidehole 1.5 cm distal to the proximal sleeve margin which was seen fluoroscopically to lie within the UES at the time of sphincter closure. Maximal UES dimensions during sphincter opening were measured fluoroscopically in the sagittal plane [12]. We measured the onset of superior and anterior motion of the hyoid and larynx as well as timing of peak antero-superior motion of these structures. Peak pharyngeal contraction amplitude and wave duration were measured from the manometric tracings of the two distal solid state transducers positioned in the hypopharynx and the midpharynx.

Duplicate values for each subject were averaged before calculation of group mean data for each volume swallowed. Statistical inferences were made regarding the bolus volume effect, cold effect, anesthesia effect, cold/volume interaction, and anesthesia/volume interaction using a two-way mixed design analysis of variance (ANOVA) for repeated measures [16]. All values are represented as mean ± SEM unless stated otherwise.

Results

There was a significant volume-dependent forward shift in the timing of events culminating in UES opening (hy-

Table 1. Timing of swallow events in reference to the onset of tongue tip motion at maxillary incisors

Variable	Volume (ml)	Control	Tonsillar pillar treatment: Cold stimulation	Tonsillar pillar treatment: Anesthesia	Statistical comparisons: Cold stimulation: Volume effect (p)	Cold stimulation: Cold effect (p)	Cold stimulation: Vol/Cold interaction (p)	Anesthesia: Volume effect (p)	Anesthesia: Anesthesia effect (p)	Anesthesia: Vol/Anesth. effect (p)
Bolus head arrives	2	0.24 ± 0.02	0.22 ± 0.03	0.21 ± 0.02	0.001	NS	NS	0.001	0.04	NS
posterior tonsillar pillar	20	0.00 ± 0.04	−0.02 ± 0.05	−0.05 ± 0.04						
Anterior hyoid onset	2	0.31 ± 0.05	0.32 ± 0.03	0.33 ± 0.05	0.0001	NS	NS	0.007	NS	NS
	20	0.15 ± 0.02	0.13 ± 0.03	0.20 ± 0.04						
Anterior laryngeal onset	2	0.42 ± 0.04	0.46 ± 0.03	0.42 ± 0.06	0.0001	NS	NS	0.0007	NS	NS
	20	0.21 ± 0.03	0.21 ± 0.03	0.26 ± 0.05						
Epiglottal closure	2	0.51 ± 0.05	0.58 ± 0.04	0.52 ± 0.06	0.0002	NS	NS	0.007	NS	NS
	20	0.31 ± 0.04	0.24 ± 0.05	0.34 ± 0.08						
Soft palate elevation	2	0.09 ± 0.04	0.06 ± 0.05	−0.03 ± 0.05	0.0001	NS	NS	0.001	NS	NS
onset	20	−0.16 ± 0.05	−0.21 ± 0.06	−0.22 ± 0.07						
Soft palate elevation	2	0.22 ± 0.04	0.26 ± 0.05	0.15 ± 0.05	0.0005	NS	NS	0.002	NS	NS
complete	20	0.02 ± 0.05	−0.05 ± 0.07	0.04 ± 0.06						
UES relaxation onset	2	0.43 ± 0.04	0.47 ± 0.03	0.44 ± 0.05	0.0001	NS	NS	0.0001	NS	NS
	20	0.16 ± 0.05	0.10 ± 0.04	0.19 ± 0.06						
UES relaxation	2	0.57 ± 0.04	0.55 ± 0.05	0.57 ± 0.04	0.0001	NS	NS	0.0001	NS	NS
maximum	20	0.30 ± 0.05	0.24 ± 0.03	0.30 ± 0.06						
UES open	2	0.58 ± 0.05	0.60 ± 0.04	0.64 ± 0.05	0.0001	NS	NS	0.0001	NS	NS
	20	0.33 ± 0.03	0.32 ± 0.03	0.33 ± 0.03						
UES closure	2	1.06 ± 0.06	1.12 ± 0.04	1.10 ± 0.04	NS	NS	NS	NS	NS	NS
	20	0.95 ± 0.03	0.97 ± 0.04	0.97 ± 0.03						

Values: X ± SEM.

oid and laryngeal motion, UES relaxation and opening, epiglottal and palatal closure) referenced to the onset of tongue tip motion at the posterior surface of the maxillary incisors under all three experimental conditions ($p < 0.02$) (Table 1).Neither cold stimulation nor anterior tonsillar pillar anesthesia influenced the effect of bolus volume on the coordination of relaxation and opening. That is, the volume-dependent forward shift in timings remained significant under all experimental conditions and the interaction terms, cold/volume, and anesthesia/volume did not reach statistical significance (Table 1, Fig. 1).

Regional transit times, pharyngeal clearance time, and total swallow duration were not influenced significantly by swallowed bolus volume or cold stimulation (Table 2). Following topical anesthesia to anterior tonsillar pillars, pharyngeal clearance time was prolonged significantly for 2- and 20-ml boluses, respectively (0.82 vs. 0.91 sec; 0.95 vs. 1.06 sec; $p = 0.002$). From Figure 2 it can be seen that this effect is a consequence of earlier entry of the bolus head into the oropharynx whereas the onset of the pharyngeal swallow response and overall swallow duration are unchanged.

Following topical anesthesia to the anterior tonsillar pillars there is a significant prolongation in the time interval between the arrival of the head of the bolus at the posterior tonsillar pillars and onset of anterior hyoid motion ($p = 0.03$), UES opening ($p = 0.01$), and UES closure ($p = 0.002$) (Fig. 3). The earlier arrival of the bolus head at the tonsillar pillars under conditions of anesthesia

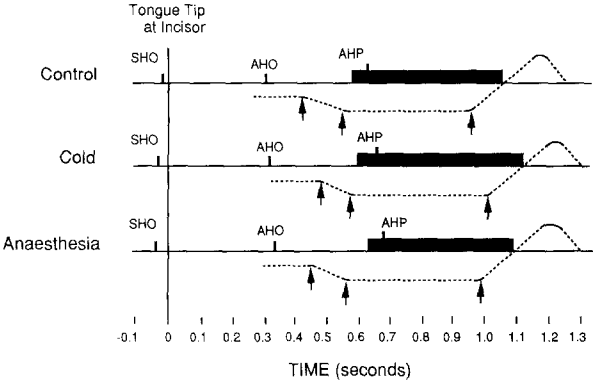

Fig. 1. The effects of cold stimulation and anterior tonsillar anesthesia on coordination of UES relaxation and opening referenced to the initial motion of the tongue tip at the incisors. Data shown here are group mean timings in response to a 2 ml bolus. Arrows under the stylized manometric profile of UES pressure represent UES relaxation onset, maximum relaxation, and relaxation offset (stated in the methods). The black bar represents the interval or barium flow across the UES determined radiologically. Neither cold stimulation nor anterior tonsillar pillar anesthesia influenced the timing of hyoid movement, UES relaxation profile, opening, closure, and duration of flow. SHO, superior hyoid onset; AHO, anterior hyoid onset; AHP, anterior hyoid peak.

accounts for prolongation in these intervals whereas the onset of the pharyngeal phase was not delayed by anesthesia (Fig. 2). Topical anesthesia did not influence the coordination of UES relaxation and opening when referenced to bolus head arrival at the tonsillar pillars (Fig. 3).

Peak amplitudes of peristaltic waves in the midpharynx were neither influenced significantly by bolus

Table 2. Regional transit times and pharyngeal clearance times

					Statistical comparisons					
			Tonsillar pillar treatment		Cold stimulation			Anesthesia		
Regional transit/ clearance times	Volume (ml)	Control	Cold stimulation	Anesthesia	Volume effect (p)	Cold effect (p)	Vol/Cold interaction (p)	Volume effect (p)	Anesthesia effect (p)	Vol/Anesth. effect (p)
Oral transit	2	0.42 ± 0.04	0.48 ± 0.03	0.46 ± 0.04	NS	NS	NS	NS	NS	NS
	20	0.37 ± 0.02	0.37 ± 0.03	0.40 ± 0.03						
Pharyngeal transit	2	0.64 ± 0.03	0.64 ± 0.03	0.64 ± 0.03	NS	NS	NS	NS	NS	NS
	20	0.57 ± 0.02	0.60 ± 0.03	0.60 ± 0.02						
Pharyngeal clearance	2	0.82 ± 0.04	0.89 ± 0.04	0.91 ± 0.04	0.047	NS	NS	0.009	0.002	NS
	20	0.95 ± 0.03	0.99 ± 0.05	1.06 ± 0.05						

Values: X ± SEM.

Table 3. Temporal measures in reference to the arrival of the head of the bolus at the posterior tonsillar pillar

					Statistical comparison					
			Tonsillar pillar treatment		Cold stimulation			Anesthesia		
Variable	Volume (ml)	Control	Cold stimulation	Anesthesia	Volume effect (p)	Cold effect (p)	Vol/Cold interaction (p)	Volume effect (p)	Anesthesia effect (p)	Vol/Anesth. interaction (p)
Anterior hyoid onset	2	0.07 ± 0.04	0.10 ± 0.03	0.13 ± 0.05	NS	NS	NS	NS	0.03	NS
	20	0.15 ± 0.04	0.16 ± 0.06	0.26 ± 0.06						
Anterior laryngeal peak	2	0.43 ± 0.05	0.51 ± 0.04	0.45 ± 0.07	NS	NS	NS	NS	NS	NS
	20	0.49 ± 0.03	0.51 ± 0.05	0.61 ± 0.06						
Epiglottal closure	2	0.27 ± 0.04	0.35 ± 0.04	0.33 ± 0.08	NS	NS	NS	NS	NS	NS
	20	0.30 ± 0.04	0.27 ± 0.05	0.42 ± 0.08						
Tail at tonsillar pillar	2	0.28 ± 0.06	0.28 ± 0.03	0.29 ± 0.04	NS	NS	NS	0.03	NS	NS
	20	0.38 ± 0.02	0.39 ± 0.05	0.45 ± 0.04						
UES open	2	0.34 ± 0.03	0.38 ± 0.04	0.43 ± 0.05	NS	NS	NS	NS	0.01	NS
	20	0.33 ± 0.02	0.34 ± 0.05	0.39 ± 0.04						
UES relaxation onset	2	0.19 ± 0.04	0.26 ± 0.04	0.25 ± 0.05	NS	NS	NS	NS	NS	NS
	20	0.20 ± 0.05	0.20 ± 0.05	0.26 ± 0.05						
UES relaxation maximum	2	0.32 ± 0.03	0.38 ± 0.04	0.39 ± 0.05	NS	NS	NS	NS	NS	NS
	20	0.33 ± 0.05	0.31 ± 0.05	0.38 ± 0.04						
UES relaxation offset	2	0.73 ± 0.04	0.81 ± 0.04	0.81 ± 0.04	NS	NS	NS	0.03	NS	NS
	20	0.87 ± 0.03	0.87 ± 0.05	0.90 ± 0.05						
UES closure	2	0.82 ± 0.04	0.89 ± 0.04	0.91 ± 0.04	NS	NS	NS	0.01	0.002	NS
	20	0.95 ± 0.03	0.99 ± 0.05	1.06 ± 0.05						

Values: X ± SEM.

volume nor by any of the three experimental conditions (Fig. 4). The statistically significant volume-dependent increase in sagittal and transverse UES diameters ($p = 0.0001$) was not influenced by cold stimulation or anesthesia.

Discussion

The major findings of this study are that neither cold stimulation nor local mucosal receptor blockade of the anterior tonsillar pillars influence the temporal relationships among the motor events of the normal pharyngeal swallow, suggesting that elicitation of the normal pharyngeal swallow response is not mediated by mucosal sensory receptors at the anterior tonsillar pillars. These findings do not support the reflex chain hypothesis that the pharyngeal response is a "triggered" reflex dependent on faucial mucosal sensory receptors. Pharyngeal clearance was prolonged with topical anesthesia and was accounted for by the early arrival of the bolus head into the pharynx ("pre-swallow spill" phenomenon). This effect may relate to the earlier motion of the bolus head in the context of impaired sensation in the region of the tonsillar pillars thereby influencing the integrity of the glossopalatal sphincter in the predeglutitive control of the bolus. Because the preswallow spill was not associated with pharyngeal swallow response, there was no change in timing of swallow events when referenced to the onset of the swallow. Although the preswallow spill has been perceived to indicate a delayed pharyngeal swallow response, it may represent the inability of the oral cavity to adapt to a larger volume [17]. A significant proportion of normal swallows has been shown to occur after the head of the bolus passes the anterior tonsillar pillars, indicating that induction of a reflex swallow may involve stimu-

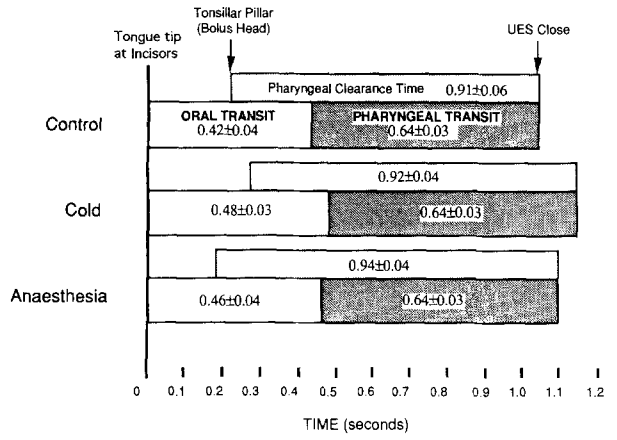

Fig. 2. Effect of cold stimulation and anterior pillar anesthesia on regional transit and clearance times for 2 ml barium bolus. There is no significant difference in oral and pharyngeal transit or pharyngeal clearance with cold stimulation. Note that pharyngeal clearance was prolonged under conditions of anterior tonsillar anesthesia ($p = 0.002$) due to earlier arrival of bolus head at posterior tonsillar pillars.

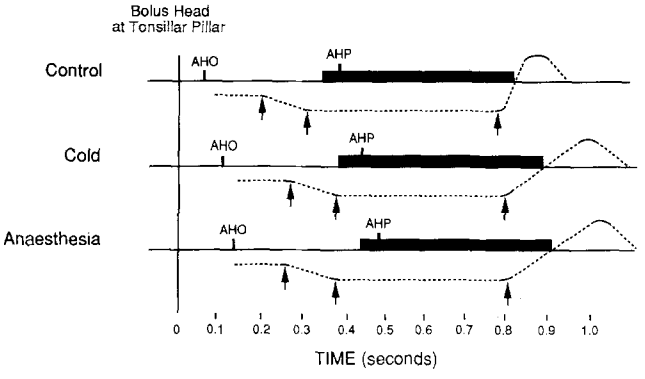

Fig. 3. Effect of regional anesthesia on the pharyngeal-UES coordination. Shown here schematically are group mean timings in response to 2 ml barium swallows. In this case, timings are in reference to the timing of the arrival of bolus head at posterior tonsillar pillars. Cold stimulation did not significantly influence pharyngo-sphincteric coordination. The only significant findings were a delay in onset of anterior hyoid motion ($p = 0.3$), UES opening ($p = 0.1$), and UES closure ($p = 0.002$) following anterior tonsillar pillar topical anesthesia. Comparison of these data with Figure 2 confirms that this observation is due to earlier arrival of the bolus head at the tonsillar pillars rather than to any alteration in UES function brought about by anesthesia.

lation of a broad zone within the pharynx rather than a stereotyped response to a focal stimulus [18,19].

It is widely believed that the pharyngeal swallow response is a triggered reflex and the normal oropharyngeal swallow sequence is influenced by sensory input [1]. The importance of afferent input is demonstrated by the inability to sustain repetitive swallows at the same rate after a few swallows [6,20] and elicitation of a complete swallow entirely by peripheral stimulation of the superior laryngeal nerves [21,22]. Though stimulation of the mu-

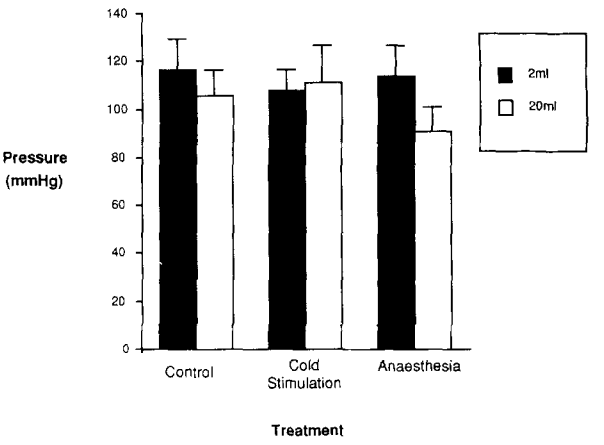

Fig. 4. Peak amplitude of midpharyngeal contraction pressure waves were not influenced by bolus volume, cold stimulation, or anterior tonsillar topical anesthesia.

cosa of the palate, uvula, epiglottis [2], and laryngopharynx [3] have been identified as trigger sites for swallow elicitation, the anterior tonsillar pillars are the most consistent [23] and most sensitive site for triggering the swallow reflex [2]. A range of stimulus types can elicit a normal swallow including liquids, light touch, and pressure [2] and cold stimulation apparently reduces pharyngeal swallow response in stroke patients [11]. Despite the above evidence for an important role of afferent input in swallow control, the entire oral-pharyngeal sequence can be elicited centrally [24–31], and we have shown that the normal swallow can be elicited despite complete mucosal anesthesia to oral/pharyngeal mucosa [32]. Therefore, afferent input may have more influence over swallow coordination than elicitation of its component parts. For example, bolus-volume and viscosity-dependent alteration in timing is likely to be mediated by sensory receptors [7,8,15]. Hence, our aim was to determine whether attempted upregulation or inhibition of putative receptors in the transitional zone (tonsillar pillars) would influence the hypothesized sensory-mediated linkage between oral and pharyngeal phases.

Our findings certainly rule out any role of mucosal thermal receptors playing a major role in elicitation of the normal pharyngeal swallow response. Other human clinical studies, with findings consistent with ours, in patients [33] and healthy volunteers [34] also support the notion that thermal receptors in this region are not important in this response. The finding by Lazzara et al. [11] that cold/tactile stimulation did facilitate the pharyngeal response may be due to local stimulation of receptors other than thermosensitive receptors. It is possible that the discrepancy among these studies is due to some effect of touch or pressure from the laryngeal mirror and not the cold per se. The inability to facilitate an earlier pharyn-

geal response in our study could indicate that healthy swallow is primed for minimal oral-pharyngeal latency and cannot be improved upon. Although we used the technique of stimulation as described previously [11,14], it is possible that to demonstrate any effect in normal swallowing, the stimulus duration of 5 sec may be too brief. However, cold is also nociceptive [35], and prolonged stimulation may induce nociceptive receptors rather then cold receptors. Although subjects in our study were older, it is unlikely that the lack of response to cold stimulation was influenced by aging. Oral sensation in general is retained with aging, showing only slight decline in tactile, vibratory, and stereognostic sensation but no decline in thermal sensation or proprioception after the age of 80 [36]. The absence of effect in our study is unlikely to be due to lack of cold receptors because cold receptors have been identified in the tongue, oropharynx, and nasopharynx [35,37] and our subjects perception of the stimulus was abolished by Xylocaine. Although there is evidence of temperature-sensitive receptor fields in the orolingual somatosensory cortex [35], it is possible that thermal pathways are poorly represented in the medullary swallow center. Regions of the nucleus tractus solitarius which integrate sensory information from the oral cavity and epiglottis are more responsive to a moving mechanical stimuli then to a focal stimuli, and least sensitive to thermal stimuli [37]. These neurons rarely respond exclusively to thermal stimulus.

The exact mechanism by which cold stimulus facilitates disordered swallowing [14,38] is unknown. However, cold is known to decrease spasticity in hemiplegic and quadriplegic patients [39] possibly by slowing motor and nerve conduction [40] and enhances muscle activity [41–43].

Our findings suggest that cold-sensitive or tactile oropharyngeal mucosal receptors do not play a key role in the temporal regulation of the normal pharyngeal swallow response. The lack of effect of cold stimulation in our study does not rule out the possibility that the pharyngeal swallow could be elicited by stimulation of deeper mechanoreceptors which have been identified in the palatopharyngeal region [44,45]. It also remains to be proven whether the entire oral-pharyngeal sequence is a preprogrammed response mediated centrally by the medullary swallow center.

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