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Dysphagia

Thermal Application Reduces the Duration of Stage Transition in Dysphagia after Stroke

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Abstract. The present study had two purposes. The first was to provide variability data on objectively measured durational parameters of swallowing as accomplished by dysphagic patients secondary to stroke. The second was to examine the short-term effects of thermal application on these same durational measures. The study employed a cross-over design with each dysphagic stroke subject swallowing 10 times in both untreated and treated conditions. Two findings emerged: (1) swallowing durations in the 22 dysphagic stroke subjects were highly variable within and across subjects and have distributions that were nonnormal with nonhomogeneous variances; (2) thermal application reduced duration of stage transition (DST) and total swallow duration (TSD). Implications of these findings are discussed.

Key words: Dysphagia — Stroke — Thermal stimulation — Rehabilitation — Deglutition — Deglutition disorders.

It is estimated that 250,000 new cases of stroke occur each year and that the prevalence is approximately 1.6 million persons [1]. Dysphagia occurs in 30%–50% of these stroke patients [2]. Ample evidence confirms that those strokes that are multiple [3–6], bilateral [7–9], or involving the brainstem [3,5,10,11] can cause severe, chronic swallowing problems. Even unilateral cortical or subcortical strokes [3,12–16] can impair the swallow, sometimes for weeks or months, and in rare cases, for much longer. For the most part, these findings are based on videofluoroscopic swallowing examinations, the procedure that has emerged as the gold standard for evaluating abnormal swallowing.

Systems for classifying the signs of dysphagia as revealed by videofluoroscopic evaluation have also appeared [17,18]. These signs are traditionally divided into groups including those of duration, stasis, and penetration-aspiration. Duration of stage transition (DST), defined by Robbins et al. [18] as the elapsed time between the arrival of the head of the bolus at the posterior margin of the ramus and the beginning of maximum elevation of the hyoid bone during the swallow, has acquired special significance. Abnormally long DST is a common sign of dysphagia resulting from stroke regardless of the number or localization of lesions [4]. Furthermore, it is posited that an abnormal DST increases the likelihood of aspiration [19]. An abnormally long DST is also one of the main criteria [20] for initiating a popular form of dysphagia therapy called thermal stimulation [21] or tactile-thermal application (TTA) [22]. The method as originally described [17] requires that a clinician touch or stroke one or both of a patient's faucial pillars several times with a cold probe after which the patient is urged to swallow. Its purpose, according to Logemann [19], is to heighten the sensitivity for the swallow in the oral cavity so that when the patient voluntarily attempts to swallow, he or she will trigger a reflex more rapidly.

A recent survey [20] revealed that 78% of Veterans Hospitals use some form of TTA for the treatment of dysphagia. Unfortunately, data on the method's efficacy are in short supply. Lazzara et al. [21] studied the

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immediate effects of thermal stimulation on oral, pharyngeal, and total transit times for 25 patients with various neurologic diseases. Their experimental protocol required three liquid and three semisolid swallows, with thermal stimulation being provided before the third swallow. Some patients failed to complete the protocol. They summarize their findings by observing that stimulation "improved triggering of the swallowing reflex in 23 of these 25 neurologically impaired patients on swallows of at least one consistency." Results from a different protocol with a limited number of patients suggested that the effects of a single sensitization lasted for two to three swallows [21].

Selinger et al. [23] reported the effects of 9 days of thermal stimulation with a patient whose dysphagia resulted from a brainstem stroke. Two modified barium swallow evaluations before treatment confirmed severe, stable dysphagia. After 26 sessions of thermal stimulation during 9 days, repeat testing revealed no reduction in aspiration. Swallow durations, the usual measure of improved triggering of the swallow, were not measured.

Rosenbek et al. [4] completed a treatment trial with 7 dysphagic patients whose signs included abnormally long DSTs. The 7 whose dysphagia resulted from multiple ischemic lesions underwent a 1-month trial of thermal stimulation (called thermal application in their study) using a four-period (ABAB) cross-over design. After baseline testing, 6 of the subjects were randomly assigned to begin the study with a week of thermal application (B stage), and 1 subject was randomly assigned to begin with a week of no treatment (A stage). Week-long A and B stages were then alternated until each subject had completed the 4-week study. Progress was tested after each stage and at follow-up 1 month later. Three judges determined the influence of thermal application on eight duration and four descriptive measures by visual inspection of data displays. Two of the judges agreed that 2 subjects demonstrated decreased DST secondary to treatment, without changes in the occurrence of aspiration or penetration. The authors concluded that these findings offered weak support for the method's efficacy. Baseline testing consisted of three swallows preceded by thermal application and three that were not. The untreated and treated swallows were compared. The judges' impressions were that the immediate effects of thermal application may well have been substantial, but that response variability made confident conclusions impossible.

Two conclusions emerge from the research done thus far: (1) short-term effects of thermal application may be substantial even if long-term effects are not; (2) subsequent studies need to be designed to control for the variability of the abnormal swallowing response.

The purposes of the present study were to provide variability data on objectively measured durational parameters of swallowing as accomplished by patients made dysphagic by stroke, and to examine the short-term effects of thermal application on these same durational measures. The study employed a crossover design with each dysphagic stroke subject swallowing 10 times in both untreated and treated conditions. The order of conditions was randomized.

Methods

Subjects

Twenty-three individuals (22 males and 1 female) with a medical history significant for multiple ischemic lesions resulting from one or more strokes and dysphagia were recruited from the inpatient and outpatient populations of the William S. Middleton Memorial Veteran's Hospital. Each had dysphagia resulting from stroke defined as a report of swallowing difficulty by patient, family, or healthcare provider. One subject was not able to complete the experimental protocol because of large aspirations on two consecutive swallows, and was excluded from the analysis. The remaining 22 subjects completed this protocol without complications. Subjects ranged in age from 54–81 years (mean age 67.3). Lesion site, as described in Table 1, was determined by magnetic resonance imaging (MRI) for 13 of the 22 study participants, and computerized tomographic (CT) scan for the remainder. Thirteen patients entered the study within 1 month of exhibiting clinical signs of CVA. Six patients were studied 12 or more months postictus (seizure), and 3 were included approximately 6 months poststroke. Prior to participation, all patients were deemed medically stable and cognitively intact as measured by neurologic examination and the Mini-Mental Status Examination [24] administered by a staff neurologist.

Videofluoroscopic Procedure

Swallows were evaluated during one videofluoroscopic session composed of two experimental conditions. All images were obtained in the lateral plane with the fluoroscopy unit focused from the lips anteriorly to the pharyngeal wall posteriorly, and from the nasopharynx superiorly to the cervical esophagus inferiorly. Video counter numbers were recorded simultaneously on the video signal for later analysis. Each condition required patients to swallow 10 consecutive 3-ml boluses of E-Z paste (barium sulfate esophageal cream, E-Z-EM Inc., Anjou, Canada) administered with a teaspoon by an experienced clinician. Research has shown that as consistency increases, transit times increase, thus resulting in semisolid materials moving slower throughout the entire swallow [18]. A semisolid material was selected to minimize the presumed aspiration risk over the large number of consecutive trials.

Protocol

In the untreated condition, patients swallowed 10 consecutive semisolid boluses. In the treated condition, each swallow was preceded by thermal application as described by Logemann [17,19]. Briefly, one trial of TTA consisted of three brisk strokes to each of the anterior faucial pillars from approximately the base to the midpoint of this structure. Stimulation was applied with a chilled size 00 laryngeal mirror in an alternating fashion to the anterior faucial pillars (i.e., during trial 1, three strokes were delivered to the right side, then three to the left; and trial 2 consisted of three strokes to the left pillar, then three to the

Table 1. Subject information

S#	Age	Weeks post	Localization
1	63	1	Left parietal; bilateral centrum semiovale ponto-medullary junction
2	71	12	Left centrum semiovale; right genu of internal capsule; left head of caudate; bilateral putamen
3	56	1	Bilateral basal ganglia; cerebellum
4	66	29	Posterior limb of left internal capsule
5	54	1	Left parietal; right fronto-parietal
6	76	52	Right fronto-parietal; widespread subcortical lesions
7	70	1.5	Posterior limb of left internal capsule; inferior left caudate
8	73	4	Posterior limb of left internal capsule; posterior limb or right internal capsule; left basis pontis
9	64	<1	Left subcortical; bilateral basal ganglia; left fronto-parietal
10	77	32	Left pons; posterior limb of left internal capsule; widespread subcortical lesions
11	73	4	Right fronto-parietal; right parietal-occipital
12	59	3	Left ponto-midbrain junction
13	69	64	Left parietal; left occipital; widespread subcortical lesions
14	73	104	Left ponto-midbrain junction; widespread subcortical lesions
15	65	4	Left ponto-medullary junction
16	55	104	Bilateral cortical and white matter lesions in occipital lobes; bilateral centrum semiovale; cerebellar
17	74	172	Widespread subcortical lesions; right pontine
18	69	1.5	Left basal ganglia; left parieto-temporal lobes deep white matter lesions in right frontal
19	63	3	Right fronto-parietal
20	81	1	Multiple ischemic foci in basal ganglia; widespread subcortical lesions
21	68	<1	Right basal ganglia infarct; widespread subcortical lesions
22	62	3	Left occipital; left parietal; left frontal

right). Selinger et al. [25] demonstrated that "the temperature of a metal probe encased in an insulator made of ceramic" approached a "perceptually neutral" temperature approximately 6 sec after losing contact with an ice cube. To increase the likelihood that our mirror would be perceived as cold when applied to the anterior faucial pillars, we began stimulation as quickly as possible (always under 6 sec). We also asked each subject frequently if the probe "felt cold." Without exception, they reported that it was cold on at least one side. Immediately following the stimulation, a bolus was provided and patients were instructed to swallow.

The order of conditions was randomized with a 30-min rest period between conditions. Thirteen subjects first received the 10 treatment trials followed by the 10 untreated trials. The remaining 9 subjects first received the 10 untreated trials followed by the 10 treatment trials.

Analysis of Swallows

Videofluoroscopic data were randomized and analyzed without knowledge of patient identity or condition. Four hundred and thirty-five swallows were available for analysis. Five swallows were not measurable because of technical failure or the subject's excessive body and head movement. Two duration measures—duration of stage transition (DST) and total swallow duration (TSD)—based on four observations of bolus or structure events [18] and two descriptive measures—penetration and aspiration—were made for each swallow by an experienced judge. Because of their low frequency of occurrence, these descriptive measures were not analyzed further.

DST, often clinically referred to as pharyngeal "delay," is operationally defined as the time in sec from when the bolus head reaches the inferior margin of the mandibular ramus to the onset of maximum hyoid elevation [18]. TSD is operationally defined as the time in sec from when the first posterior bolus movement begins until the hyoid returns to rest [18]. DST and TSD were selected because the literature suggests that these durations should be reduced by thermal application [19].

Reliability

Intrajudge reliability was assessed several months later on a random sampling of 10% of the total number of swallows (i.e., 22 treated and 22 untreated swallows). Reanalysis of this subset of swallows by the same judge revealed that measurements were typically within one frame (mean duration = 0.0295 sec, SD 0.0438 sec; 1 frame is equivalent to 0.0333 sec). A second experienced judge who was naive about the study also completed duration measurements on these swallows to determine the extent of interjudge agreement. In comparison, both judges were within 1.4 frame(s) of each other (mean duration = 0.043 sec).

Statistical Analysis

A Shapiro-Wilk test [26] was used to ascertain whether the within-subject distributions for DST and TSD across the 10 swallows obtained for each subject were normally distributed. Homogeneity of the within-subject variation was tested by Levene's test [27]. The test uses the average of the absolute deviations instead of the mean square of the deviations as a measure of variation in order to be less sensitive to long-tailed distributions. Comparison of the within-subject variation (average absolute deviations) for treated and untreated conditions was made by the Mann-Whitney test [27]. Because of the nonnormal distributions observed, the durational measures were tested for a "fatigue" effect across the 10 consecutive swallows by first ranking the swallowing durations of each subject, averaging ranks across subjects by swallow order, and then testing for an increase in average rank with swallow order using Page's test [28] and a one-sided alpha level = 0.05.

To test for an effect of thermal stimulation on DST and TSD, summary scores for individual subjects were obtained by averaging the scores for all 10 swallows in each condition. Then the paired differences between subject mean scores in treated and untreated conditions were compared by Wilcoxon signed rank test [27] ignoring treatment order. A concern with cross-over designs is that there may be an effect of

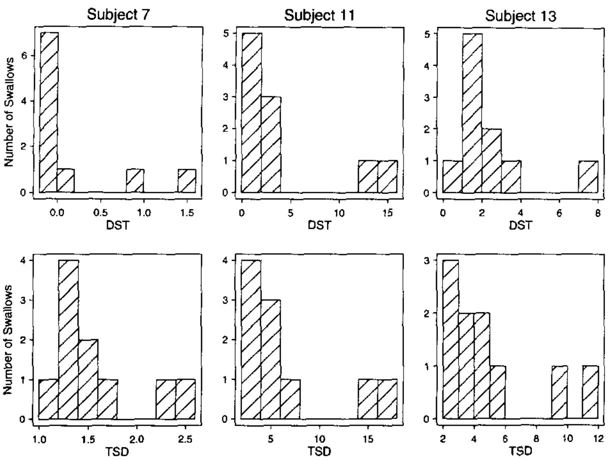

Fig. 1. Subject frequency distributions of the DST and TSD for 10 untreated swallows of three characteristic stroke subjects. Each distribution was significantly nonnormal ($p < 0.05$) by the Shapiro-Wilk test.

treatment order on the results obtained, but a Mann-Whitney test of the paired differences for an effect of treatment order was not significant ($p = 0.38$ for DST, $p = 0.26$ for TSD). All statistical testing other than Page's test for a fatigue effect employed a two-sided alpha level of 0.05 for statistical significance.

Results

Swallowing Variability

The distributions of DST and TSD across repeated swallows from the same subject tended to be nonsymmetric for both untreated and treated swallows. Theoretical durations would be bound at zero at the lower end of the range, but measured DST and TSD were both obtained by subtraction which led to some small negative values for DST. For both measures, occasional long durations were observed, resulting in distributions that tended toward positive skewness, as illustrated by the 3 subjects' data for untreated swallows depicted in Figure 1. Twelve of the 22 subjects had DST distributions across untreated swallows which were nonnormal by the Shapiro-Wilk test, and 8 of the 22 subjects had nonnormal TSD distributions across swallows.

Subjects became eligible for entry into this study by virtue of a clinical history of swallowing dysfunction, but there was considerable heterogeneity among subjects in measurements obtained from videofluoroscopic examination. Three of the 22 subjects had no untreated swallows with DSTs greater than 0.75 sec (Table 2), a modest elevation of DST on semisolid swallows for this age range [18]. Another 9 subjects had only one or two untreated swallows of 10 with a DST greater than 0.75. At the other end of the spectrum, 6 subjects had eight or more untreated swallows with a DST greater than 0.75. These same 6 subjects, and only these 6, also had at least two consecutive (of 10 untreated) swallows with a DST >1.5 sec, the criterion suggested by Lazarra et al. [21] to identify candidates for thermal stimulation. Subject mean values of DST across the 10 untreated swallows were similarly varied, ranging from −0.02 sec for subject 9 to 10.07 sec for subject 18, with a median mean value of 0.42 sec. The 6 subjects identified above had the largest mean values of DST.

There was evidence of substantial subject heterogeneity in measures of within-subject variability as well. The difference among subjects in within-subject variability for both treated and untreated swallows was highly significant ($p < 0.0001$) for both DST and TSD. There was a clear tendency for subjects with longer mean durations to have greater variability, but coefficients of variation still varied widely across subjects, particularly for DST (0.38–3.20 for DST, excluding subjects 9 and 19 with 0 means vs. 0.10–0.81 for TSD). The difference between the treated and untreated within-subject variability also varied significantly ($p < 0.0001$) across subjects for both measures. Thermal stimulation appeared to decrease within-subject variability for some subjects (those with longer swallow durations and larger variability initially) but not all subjects.

The subject rankings of swallow duration were averaged across subjects and plotted by swallow order from 1 to 10 (Fig. 2). There is evidence for a modest "fatigue" effect (increase in average rank with swallow order) for DST, particularly for treated swallows (one-sided $p = 0.05$ for untreated and $p < 0.05$ for treated swallows). There is, however, no evidence of a fatigue effect for TSD (one-sided $p > 0.05$ for both untreated and treated swallows).

Efficacy of Thermal Application

Both DST and TSD of the 10 swallows preceded by thermal stimulation were significantly shorter than those of untreated swallows (Table 3). The median decrease in DST with treatment for the 22 subjects was 0.15 sec, or 36% of the median DST of untreated swallows ($p = 0.046$). Fifteen of the 22 subjects had mean DST levels for treated swallows that were less than those of untreated swallows. Five of the 6 subjects identified as having the greatest delays had decreases in DST with treatment. These subjects also tended to have the largest treatment responses (Fig. 3a), in an absolute but not relative sense.

The median decrease for TSD was 0.22 sec, or 10% of the median TSD of untreated swallows ($p = 0.005$). Eighteen of the 22 subjects had reductions in their mean TSD with treatment, including all 6 of the

Table 2. Summary statistics by subject for 10 untreated swallows

		DST				TSD			
Subject	# Slow[b]	Mean	SD	Min	Max	Mean	SD	Min	Max
1	6	0.83	0.73	0.00	2.01	2.21	0.95	0.97	3.95
2	1	0.31	0.35	−0.11	1.16	1.67	0.32	1.20	2.32
3	2	0.72	0.29	0.46	1.25	1.96	0.20	1.75	2.35
4	1	0.40	0.43	−0.09	1.45	1.61	0.53	0.82	2.43
5	4	0.45	0.44	−0.06	0.98	1.57	0.46	0.77	2.12
6	9	2.10	0.79	0.57	3.29	3.54	0.84	2.11	4.73
7	2	0.22	0.53	−0.07	1.46	1.57	0.47	1.07	2.52
8	1	0.24	0.39	−0.17	1.04	2.65	2.14	1.02	6.87
9	0	−0.02	0.20	−0.14	0.55	1.44	0.25	1.23	1.93
10	1	0.17	0.41	−0.12	1.00	2.80	0.75	2.27	4.80
11	9	4.07	5.08	0.67	14.3	6.55	4.93	3.10	16.9
12	4/9[a]	1.04	0.62	0.55	2.35	2.24	0.66	1.66	3.61
13	9	2.35	1.98	0.48	7.52	4.86	3.13	2.20	11.8
14	1/9*	0.16	0.51	0.06	1.52	1.76	0.78	0.85	3.28
15	1	0.26	0.82	−0.04	2.58	1.75	0.78	1.08	3.79
16	0	0.24	0.17	−0.03	0.53	1.22	0.25	0.84	1.66
17	1	0.12	0.35	−0.07	0.97	2.91	0.42	2.34	3.46
18	10	10.1	5.92	2.30	19.0	11.7	6.08	3.43	20.3
19	0	0.00	0.20	−0.24	0.30	1.42	0.58	0.70	2.46
20	8	1.23	0.76	−0.16	2.43	3.30	1.36	0.83	5.43
21	8	1.77	1.89	0.03	6.60	3.86	2.05	1.47	8.70
22	3	0.72	0.49	0.03	1.53	2.39	0.72	1.17	3.50

[a]Only nine of the ten swallows were analyzable.
[b]Slow is defined as a duration greater than 0.75 sec.
Abbreviations: DST = duration of stage transition, TSD = total swallow duration, # Slow = number of swallows with DST > 0.75 sec, SD = standard deviation, Min = minimum, Max = maximum.

subjects with greatest pharyngeal delay. The effect of the thermal stimulation on TSD appears to be largely due to its effect on DST (Fig. 3b) (r = 0.88, $p < 0.001$).

Because of the nonnormality of the distributions of swallowing durations across the repeated swallows for subjects, we also compared treated and untreated swallows with respect to subject scores which were *median* (rather than mean) durations for the 10 swallows in each condition. Equivalent results on the effectiveness of thermal stimulation in reducing durations were obtained. Similarly, because some evidence for a fatigue effect was obtained, we also compared treated and untreated swallows with respect to subject scores which were averages over only the first five swallows in each condition. Treatment differences were significant in this analysis as well.

Discussion

Two findings emerge from this study. The first is that swallowing durations in 22 dysphagic, stroke subjects were highly variable within and across subjects and have distributions that were nonnormal with nonhomogeneous variances. The second is thermal application significantly reduced DST and TSD. Both findings have implications for both clinical and research activity in dysphagia.

Variability

For the clinician, the challenges posed by variability are in deciding how many swallows to elicit and how to interpret performance on what is perforce a limited number of swallows available from the typical clinical videofluoroscopic swallowing examination. The challenge is trenchant for subject 21, for example. The range of his DSTs was 0.03–6.60 (Table 2). Overall, of course, he is neither consistently slow nor normal. The challenge then is to decide if treatment is necessary and if so, what that treatment should be. Setting aside for a moment the reality that treatment decisions are based on more than just swallow durations, this kind of variability creates a clinical dilemma. If the clinician's decision is that this patient is slow even though he has some normally fast swallows, then tactile application may be appropriate. If his normal swallows are highlighted, then no treatment, at least for duration, need be employed. The treatment implication of simply calling his swallow variable is less clear. For example, it is unknown whether the risk of aspiration is greater for a patient with mild but consistent delay than it is for one with a mix of normal and severely abnormal delays. These relationships need to be investigated if duration measures are to continue as enrollment criteria for various treatments and as outcome measures for estab-

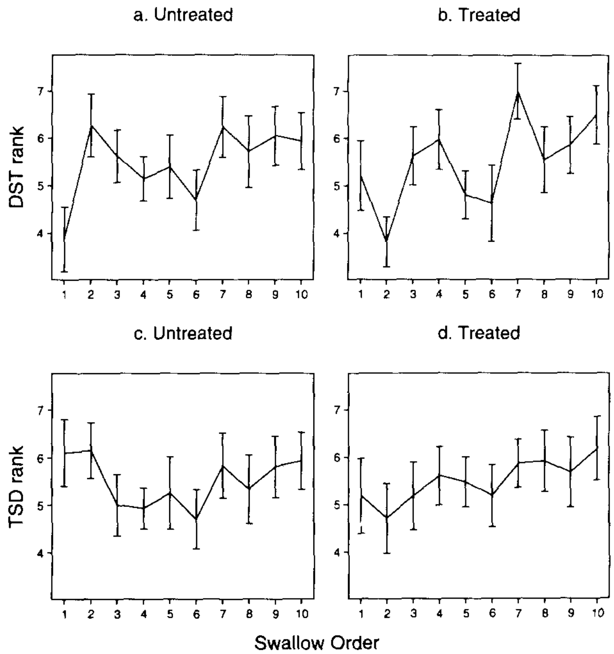

Fig. 2. Mean (±SE) within-subject rankings of swallow durations by swallow order for untreated and treated swallows. There was a modest fatigue effect (increase in average rank for increasing swallow order) for the DST (one-sided $p = 0.05$ for untreated and $p < 0.05$ for treated swallows). There was no evidence of a fatigue effect for TSD (one-sided $p > 0.05$ for both untreated and treated swallows).

lishing efficacy or for some other research or economic purpose.

Variability also has implications for all data analysis in dysphagia research. The choice of appropriate summary statistics or analysis procedures for these kinds of data is not straightforward, and various alternatives including nonparametric approaches need to be considered. In addition, designers of group efficacy studies may want to include some control over subject heterogeneity during subject selection. Clinical wisdom in speech-language pathology holds that mild and moderate patients have brighter prognoses for improvement with treatment than severe ones. Controlling severity by controlling homogeneity on measures of delay would allow testing of that wisdom.

Why are these duration measures variable within and across subjects? Part of the reason rests with the nature of the swallow response. It is not a reflex. Logemann and Kahrilas [10] describe it as "composed of closely coordinated, but potentially modifiable components, rather than a single reflexive act". Kennedy and Kent [29] echo this notion in their description of the normal swallowing event as a "continuum of variability" with the oral stage being most variable and the esophageal stage being the least. It can be hypothesized that abnormal swallows, with the possible exception of the very mild and the profoundly severe, are characterized by less competent coordination and even more variability than normal swallows. It can also be hypothesized that variability is increased by the artificial circumstances created by testing. Fortunately, the treatment in this study was robust enough to be efficacious despite all these sources of variability.

Efficacy

The finding that thermal application modifies DST supports the earlier report of Lazarra et al. [21] and the observation by Rosenbek et al. [4] that dramatic effects of thermal application could be seen on liquid swallows when untreated and treated swallows were compared during baseline testing in their study. On the other hand, the evidence for more enduring effects is relatively weak [4]. The relatively meager literature must be replicated, assuming it is logical to expect that thermal application should be therapeutic. There are reasons why the method is logical.

Some logic is supplied by what is known about swallowing anatomy and physiology. The oral cavity has sensory fibers that respond only to temperature, fibers that respond both to temperature and touch/pressure, and those that respond to touch-pressure alone [30]. Central neurons that respond to cold have been identified primarily in the more caudal region of the trigeminal sensory nucleus [30]. Those sensory fibers that respond to both temperature and touch/pressure appear to be distributed throughout the trigeminal system [31]. Fibers responding to touch/pressure alone are prominent in the faucial pillars [32] and are transmitted by the superior laryngeal nerve (SLN) to nucleus tractus solitarius (NTS). Hence, the anatomy critical to a method that provides temperature and touch/pressure stimulation is established.

Miller [33], as part of his effort to lay the physiologic groundwork for a variety of swallowing treatments, has specified the criteria based on previous investigations that sensory stimuli must meet if they are to evoke swallowing. Those of greatest relevance to the present study will be reviewed here. One is that the stimulus must excite several different kinds of sensory fibers. Thermal application, as employed in this study, provided touch-pressure and cold stimulation. Another criterion is that the sensations most likely to influence swallowing with the lowest threshold travel along the SLN. The anterior faucial pillars, which are the primary site of traditional thermal stimulation, are primarily innervated by the glossopharyngeal nerve which in experimental animals has a higher threshold to evoke swallowing. Sensation transmitted along the glossopharyngeal nerve synapses within the brainstem at the level of NTS. Another criterion is that the application of the stimulus be dynamic rather

Table 3. The effect of thermal stimulation on subject scores (mean values for 10 swallows in each condition) for DST and TSD

	DST				TSD			
	Mean (SE)	Median	Min	Max	Mean (SE)	Median	Min	Max
Untreated (n = 22)	1.25 (0.47)	0.42	−0.02	10.1	2.96 (.50)	2.22	1.22	11.7
Treated (n = 22)	0.89 (0.38)	0.38	−0.08	8.48	2.44 (.40)	2.00	1.11	10.2
Diff[a] (n = 22)	−0.35 (0.19)	−0.15	−3.61	0.96	−0.52 (.20)	−0.22	−3.4	0.83
p-value[b]		0.046				0.005		

[a]Treated subject score minus untreated subject score.
[b]Signed rank test comparing subject scores for treated and untreated swallows.
Abbreviations: SE = standard error, Min = minimum, Max = maximum, Diff = difference.

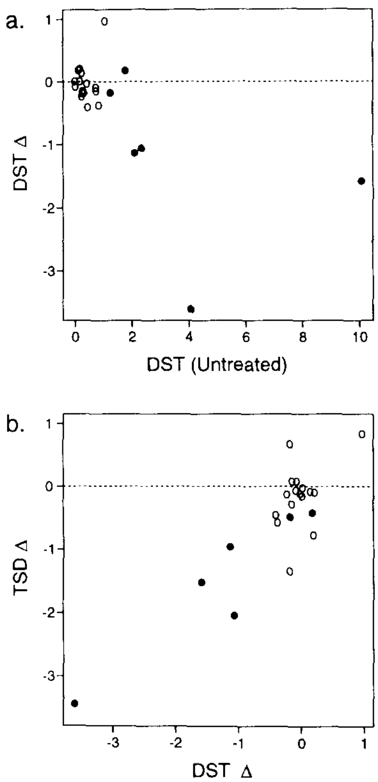

Fig. 3. The DST response to treatment (DSTΔ) and its relationship to **(a)** the DST for untreated swallows and **(b)** the TSD response (TSDΔ). Response measures were obtained by subtracting the subject average durations for 10 untreated swallows from the subject average durations for 10 treated swallows. Closed circles indicate the 6 subjects with eight or more untreated swallows having a DST >0.75 sec.

than static. The emphasis in thermal application is on rubbing or otherwise moving the applicator against the faucial pillars rather than merely touching them. Whether the direction, rate, or pressure of the stimulus is critical is to be determined, as is the importance of the location and extent of stimulation. In the present study, we rubbed briskly over a large extent of both left and right anterior faucial pillars and asked each patient to confirm that the stimulus was obvious and not painful. Another criterion is that sensory information from the oral cavity, if it is to influence the swallow, must synapse in what Miller [34] has called the dorsal region of the brainstem swallowing center. This dorsal region includes NTS and the surrounding reticular region. Paradoxically, temperature may have the fewest inputs to NTS. Presumably NTS receives input from the trigeminal sensory nuclei [35], a critical connection if the main temperature input into the swallowing center is to occur.

This anatomic and physiologic information is important as a rationale for continued experimentation with thermal application. Its greater importance, however, may be as a guide to the method's refinement. The majority of fibers in the SLN are devoted to sensation created by fluid [33]. In a subsequent study [36], ice sticks rather than probes were used. Because the ice stick melts, fluid is added to the stimulation and it may be that a third sensory modality will augment the treatment effect. Liquid alone may be enough to have a therapeutic effect on the swallowing response. Data from that study are being analyzed. Taste from the posterior one-third of the tongue also is carried to NTS via cranial nerve IX [37]. Experimentation with a sour bolus is also underway by Logemann et al. [38]. It remains for clinical researchers to compare types of stimulation and identify the most efficient and efficacious program, bearing in mind that not only pattern of dysphagia but patient age [39] may affect response to treatment.

The present study does not answer all the questions about proper stimulation, but it does demonstrate that selected swallowing durations can be modified. At issue is how sensory stimulation changes swallowing behavior. Two mechanisms can be hypothesized, if it is assumed that the cold probe is responsible for the changes. In one it is posited that augmented sensory stimulation lowers the threshold necessary to evoke a swallow. In this scenario, a bolus arriving at the faucial pillars and posterior tongue is more likely to elicit a swallow. In the second, it is posited that the threshold remains the same but that a summation of sensory inputs results in the greater likelihood of a swallow response [40]. The critical experiments to distinguish among these hypotheses have not been done. Short-term effects of thermal application such as were observed in this study could occur if either hypothesis is correct. Long-term effects, which thus far appear more illusory, would seem to depend on the first hypothesis' viability.

Thermal application's place in the armamentarium of behavioral dysphagia treatments is yet to be established. Data are accumulating slowly, and unfortunately somewhat haphazardly. Subject selection criteria need to be further worked out. DST or any other single or combination of duration measures may be inadequate. Co-occurring aspiration may strengthen subject selection as may the co-occurring need for dietary or other changes that influence the patient's quality of life. If duration measures survive as criteria, their nonnormal and nonhomogeneous variability must be accounted for. Measures of delay cannot stand alone as outcome measures; they must be combined with measures of disability and handicap [41]. Demonstrating that a method not only modifies physiology but also changes functional ability and social and psychologic variables is the acid test of its efficacy. Nor can disability and handicap measures stand alone. Dysphagia is a physiologic disorder with consequences for function and quality of life. Just as the cancer researcher begins by measuring a treatment's effect on the cancer, so the dysphagia researcher begins by documenting a treatment's effect on the physiologic signs of dysphagia. A cancer treatment that has no simultaneous functional or quality of life consequences is less efficacious than one that does. The same is true in dysphagia. An additional need then is to develop disability and handicap measures for dysphagia research. Programmatic research will eventually give definitive answers about thermal application's efficacy. The present study is but one contribution to that programmatic effort.

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