AJSLP AMERICAN JOURNAL OF SPEECH-LANGUAGE PATHOLOGY

Variability of the pressure measurements exerted by the tip of laryngoscope during laryngeal sensory testing: A clinical demonstration

Journal:	*American Journal of Speech-Language Pathology*
Manuscript ID	AJSLP-16-0006.R4
Manuscript Type:	Clinical Focus
Date Submitted by the Author:	05-May-2017
Complete List of Authors:	Kaneoka, Asako; Boston University College of Health and Rehabilitation Sciences Sargent College; The University of Tokyo Hospital, Rehabilitation Center Pisegna, Jessica; Boston University College of Health and Rehabilitation Sciences Sargent College; Boston University Medical Center, Department of Otolaryngology-Head and Neck Surgery Krisciunas, Gintas; Boston University Medical Center, Otolaryngology - Head and Neck Surgery Nito, Takaharu; The University of Tokyo Hospital, The Department of Otolaryngology LaValley, Michael; Boston University School of Public Health, Department of Biostatistics Stepp, Cara; Boston University, Speech, Language, and Hearing Sciences; Boston University School of Medicine, Otolaryngology-Head and Neck Surgery Langmore, Susan; Boston University College of Health and Rehabilitation Sciences Sargent College; Boston University School of Medicine, Otolaryngology-Head and Neck Surgery
Keywords:	Dysphagia, Swallowing, Adults

TITLE PAGE

Article title Variability of the pressure measurements exerted by the tip of laryngoscope during laryngeal sensory testing: A clinical demonstration

Authors

Asako Kaneoka, MS[1,2*]

Jessica M. Pisegna, MS, MEd[1,3]

Gintas P. Krisciunas, MPH, MA [3]

Takaharu Nito, MD, PhD. [4]

Michael P. LaValley, PhD. [5]

Cara E. Stepp, PhD. [1,3]

Susan E. Langmore, PhD, CCC-SLP [1,3]

Affiliations

1. Department of Speech, Language & Hearing Sciences, Boston University Sargent College, Boston, MA, USA
2. The University of Tokyo Hospital Rehabilitation Center, Tokyo, Japan
3. Department of Otolaryngology-Head and Neck Surgery, Boston University Medical Center, Boston, MA, USA
4. Department of Otolaryngology, University of Tokyo School of Medicine, Tokyo, Japan
5. Department of Biostatistics, Boston University School of Public Health, Boston, MA, USA

Corresponding author

Asako Kaneoka, MS*

The University of Tokyo Hospital, Rehabilitation Center

7-3-1, Bunkyo-ku, Hongo, Tokyo, Japan. 113-8655

Tel: 81-3-5800-8680, Fax: 81-3-5800-9028, Email: kaneoka@bu.edu

Abstract

Purpose: Clinicians often test laryngeal sensation by touching the laryngeal mucosa with the tip of the flexible laryngoscope. However, the pressure applied to the larynx using this touch method is unknown, and the expected responses elicited by this method are uncertain. We investigated the variability in pressure delivered by clinicians using the touch method. We also reported on the subject responses to the touches.

Methods: A fiberoptic pressure sensor was passed through the working channel of a laryngoscope, with its tip positioned at the distal port of the channel. Eight healthy adults were tested, each by two examiners. Each examiner touched the mucosa covering the left arytenoid three times. The sensor recorded the pressure exerted by each touch. An investigator noted subject responses to the touches. From the recorded videos, absence/presence of the laryngeal adductor reflex in response to touch was judged.

Results: Pressure values were obtained for 46 of the 48 possible samples, ranging from 17.9mmHg to the measurement ceiling of 350.0mmHg. The most frequently observed response was positive subject report followed by the laryngeal adductor reflex.

Conclusion: Pressure applied to the larynx using the touch method was highly variable, indicating potential diagnostic inaccuracy in determining laryngeal sensory function.

Text

Introduction

Sensory input from the laryngeal mucosa is essential for triggering protective airway reflexes (Bradley, 2000). These reflexes elicited include a cough, gag, swallow, and the laryngeal adductor reflex (LAR). The LAR is a brainstem reflex manifest as a brief vocal fold closure in response to sensory input to the laryngeal mucosa. Reduced laryngeal sensory detection, sensory processing, and/or motor output may contribute to failure of this protective reflex (Aviv et al., 1998; Aviv et al., 2002; Phua, McGarvey, Ngu, & Ing, 2005; Shock et al., 2015; Sulica, Hembree, & Blitzer, 2002), thereby increasing risk for aspiration and subsequent airway complications in patients with dysphagia (Aviv, Sacco, Mohr et al., 1997; Kaneoka, Krisciunas, Walsh, Raade, & Langmore, 2014; Onofri, Cola, Berti, da Silva, & Dantas, 2014). Thus, in order to identify patients who are at high risk for aspiration, laryngeal sensory testing has been recommended as a part of the endoscopic swallowing examination (Langmore, Kenneth, & Olsen, 1988).

Laryngeal sensation is often tested by lightly and briefly touching the laryngeal mucosa with the tip of a flexible laryngoscope (the touch method). Several studies have described the regions to touch for testing sensation: a patient's aryepiglottic folds (Langmore et al., 1988; Leow, Beckert, Anderson, & Huckabee, 2012; Onofri et al., 2014), arytenoids (Langmore et al., 1988; Onofri et al., 2014) or epiglottis (Langmore et al., 1988). Studies have reported five acceptable positive responses to the touch of an endoscope: patient report when they feel the touch (Kaneoka, Krisciunas, Walsh, Raade, & Langmore, 2015; Leow et al., 2012; Sato et al., 2002), an LAR (Domer, Kuhn, & Belafsky, 2013; Onofri et al., 2014), a cough, a gag, or a swallow (Langmore et al., 1988; Leow et al., 2012). However, several issues remain unclear regarding the touch method. First, the intensity of any touch is unknown, and may be inconsistent across trials. Touches of variable pressure may not allow subjects to respond consistently across

trials, making the diagnosis of sensory deficit unreliable. Second, it is unknown which form of response (i.e. subject report, the LAR, cough, gag, or swallow) is the most commonly observed when applying a touch. Third, inter-rater reliability in judging the absence/presence of the LAR has not been tested.

The primary purpose of this study was to investigate the variability in the pressure delivered by clinicians using the touch method. We hypothesized that there would be a large range of pressure applied to the laryngeal mucosa using the endoscopic touch method. We also hypothesized that the pressure exerted by different examiners would be different. The secondary purpose of this study was to report the types of various subject responses to the touches. We hypothesized that healthy adults would constantly demonstrate the airway protective reflexes in response to the touch. The third purpose of the study was to test raters' agreement in judging the absence/presence of the LAR in response to a touch. We hypothesized that raters' agreement would be acceptable in judging the absence/presence of the LAR.

Methods

This study was conducted in the Otolaryngology outpatient clinic of an urban teaching hospital. The study protocol was approved by the Institutional Review Board (Ref. number: H33037) and written informed consent was obtained from all subjects.

Subjects

A total of eight healthy adults with no history of trauma or surgery to the neck or larynx, no history of laryngeal malformation, no history of neurologic disease and no history of dysphagia were recruited. All subjects demonstrated the ability to understand verbal and written instructions in English. Individuals with an allergy to lidocaine and pregnant women were

excluded from the study.

Equipment interface

Figure 1 presents the equipment interface. A flexible channel fiberoptic nasolaryngoscope (FNL-10RAP; PENTAX, Lincoln Park, New Jersey, USA) was utilized for sensory testing. A fiberoptic micropressure sensor (OPP-M; OpSens, Quebec, Canada), which has been designed for human and animal physiological pressures ranging from -50.0mmHg to 350.0mmHg, was inserted through the working channel of the endoscope (FNL10-RAP; PENTAX). The tip of the sensor was positioned at the distal port of the open channel. The proximal end of the micropressure sensor cable was connected to a signal reading device (LIFESens; OpSens). LIFESens is a signal conditioner that is also optimized for measuring physiological pressures in humans and animals and is compatible with the fiberoptic micropressure sensor (sampling rate = 250Hz). The device was then connected to the Digital Swallowing Work Station (Model 7200, PENTAX). The channel scope was coupled with a light source (LH-150; PENTAX) and was connected to the Pentax camera system (PSV-4000; PENTAX). The camera system was then connected to the Digital Swallowing Work Station where pressure readings and video images of the larynx were captured simultaneously. The videos were recorded at a rate of 30 frames per sec. Calibration of the sensor was implemented using the calibration function of LIFESens before each exam according to the manufacturer instructions.

Preliminary testing

The study protocol was tested by two speech language pathologist authors (JP, SL) who

served as examiners on one examinee. In addition to the study set-up as described above, a second videolaryngoscope (VNL-1070STK; PENTAX) was connected to the Digital Swallowing Work Station, and was used as a "monitoring scope." The monitoring scope was only used in the preliminary testing phase to determine when the primary scope touched the mucosa covering the left arytenoid. The monitoring scope was passed by the first examiner through the examinee's nostril and positioned so that the larynx could be fully visualized throughout the procedure. The channel scope with the sensor was then passed by a second examiner through the other nostril and positioned so that the larynx could be fully visualized. At this time, the pressure reading from the sensor was shown on the monitor of the Digital Swallowing Work Station and the screen of the Lifesens program and verified to be at zero. Then the examiner was instructed to lightly and briefly touch the mucosa covering the left arytenoid to achieve white out for a brief moment. (Langmore et al., 1988; Onofri et al., 2014).

Figure 2 shows the image from the monitoring scope when the sensory scope touched the mucosa covering the arytenoid. When the scope touched the mucosa covering the arytenoid (A), the view from the channel scope was blocked by the mucosal surface (B). We defined the pressure for each trial as the peak pressure that occurred when the laryngoscopic view was completely blocked by the laryngeal mucosa (C).

Data collection

Data were collected from eight healthy adult subjects (four males, four females; mean age ±1SD = 39.4 ±10.6 years). The two examiners (JP, SL) administered the touch test to each subject. Examiner 1 had two years of prior experience and Examiner 2 had more than 20 years of experience using the touch method. Topical anesthesia (0.2mL of 4% lidocaine hydrochloride) was sprayed in the left nostril of each subject. The channel scope, which stored the pressure

sensor in its working channel, was lubricated with K-Y Jelly® and then passed by the first examiner through a subject's left nostril into the pharynx. Subjects were prompted to vocalize a sustained "ee" for 2 to 3 sec to assess vocal fold mobility. Then, the subjects were instructed to close their eyes to be blinded to the monitor showing the endoscopic view and to press a hand-held buzzer as soon as they felt each touch. One trial touch was applied to the mucosa covering the left arytenoid in order to give the subjects an opportunity to practice detecting what a "touch" felt like. A touch typically feels like a slight sensation of a slight poke or tap. Some subjects described it as a light scratch. Then the formal testing began.

The first examiner touched the mucosa covering the left arytenoid with the tip of the laryngoscope three times in total. The subject rested with the scope in place for at least 30 sec between touches. After each attempt, the examiner indicated whether or not they thought they had made adequate contact on the mucosa covering the arytenoid with a verbal code unknown to the subject. If the examiner indicated that they thought the sensory scope did not make contact on the mucosa covering the arytenoid based on the laryngoscopic view on the monitor, the pressure reading and subject report of the attempt were discarded, and the examiner repeated the trial. Then the second examiner performed the sensory testing in the same manner with the scope still in place. The order of the examiners was counterbalanced across the subjects. The scope remained in the subject's nostril throughout the procedure. A third speech language pathologist (AK), the author who served as an observer, recorded the subject's report, as well as presence or absence of a responsive cough, gag, and/or swallow. The two examiners were blinded to their applied pressure readings until they completed testing on all eight subjects. However, if the pressure measurement of any touch reached the maximum measurable level (350.0mmHg), the observer notified the examiner that the touch had exceeded the ceiling. This was to attempt to limit the number of additional unquantifiable measurements. After the study visit of each subject

was completed, the third speech language pathologist independently played the recorded videos of the laryngeal sensory testing along with the pressure recordings on the Digital Swallowing Workstation. The speech language pathologist then obtained the pressure for each trial as the peak pressure that occurred when the laryngoscopic view was completely blocked by the laryngeal mucosa. Every examination was monitored for adverse events, including any instances of vasovagal episodes, laryngospasms, or laceration of the mucosa.

Absence/presence of the LAR response was judged for each recorded touch by two additional speech language pathologists, with at least 10 years of experience with the touch method, who had not been present for the testing. When a brief adduction of the arytenoids or vocal folds was observed, the LAR was determined to be present. The judgments were made by reviewing the recorded videos frame-by-frame. In the case of disagreement, a third independent rater's judgment was used.

Data analysis

The range of pressures exerted by the two examiners was described in order to demonstrate the variability of the intensity of the touches. The pressure measurements exerted by the two examiners was compared by subject using two-factor analysis of variance. The generalized estimating equations approach was used to account for the within-subject correlation in the repeated measures of pressure for each subject exerted by the two examiners. Frequency of absence/presence of subject report, the LAR, cough, gag, or swallowing reflexes in response to touch was reported. Agreement between the two raters in judging absence/presence of the LAR was tested using the Kappa statistic. Statistical analyses were performed on SAS® (version 9.4; SAS Institute Inc. Cary, NC, USA).

Results

All eight subjects completed the study protocol. Complete bilateral vocal fold adduction was judged to be normal in all subjects as judged from their vocalized sustained "ee." In total, the examiners judged that 48 touches (24 touches per examiner) were successfully applied out of 56 attempts (Table1). No vasovagal episodes, laryngospasms, or lacerations of the mucosa occurred during the testing.

Pressure measurements

Of those 48 touches, two pressure measurements were not recorded due to errors with the data delivery system. Pressure values were obtained for 46 of the 48 possible samples, ranging from 17.9mmHg to the measurement ceiling of 350.0mmHg; three pressure values of the 46 readings reached the maximum measurable level of the sensor (350.0mmHg; Table1). As a result, 43 pressure measurements were used for the following statistical analyses. The mean and standard deviation of 43 pressure measurements obtained was 110.9±90.7mmHg. The mean pressure exerted by Examiner 1 and Examiner 2 was 89.4±75.8mmHg and 133.5±100.9mmHg respectively. The analysis of variance revealed that the mean pressure exerted by Examiner 1 was significantly lower than the mean pressure exerted by Examiner 2 ($p=0.03$).

Type of responses

Table 2 shows the absence or presence of each type of response to the 46 touches in which pressure values were obtained. Subject's report was the most frequently observed positive response, followed by the LAR, the swallowing reflex, the cough reflex, and the gag reflex.

1) Subject's report

Subjects reported that they felt the touch in 43 trials (93.5% of a total of 46 touches). The three touches that were not reported by the subjects had pressure readings of 22.4mmHg, 44.1mmHg and 273.7mmHg. Two of these three unreported touches did, however, elicit LARs. The endoscopic view of the third unreported touch was not of adequate quality to determine whether a LAR had or had not been elicited (Table 1).

2) The Laryngeal Adductor Reflex

Table 3 displays the initial judgments of the two independent raters for the absence/presence/cannot judge of the LAR. Agreement for judging the absence/presence/cannot judge of the LAR was tested on all the 48 trials. The raters agreed on the 41 trials of the 48 trials (85.4% agreement). The analysis yielded a kappa coefficient of 0.44 (95% CI=0.18-0.70), indicating a poor agreement between raters (McHugh, 2012). Table 3 also includes the judgements made by Rater 3 and the final judgements on the LAR. These final judgments are presented in Table 1 as the official judgements for the absence/presence/cannot judge of the LAR of this study.

The absence/presence of the LAR could be judged in 40 trials (87.0% of 46 trials), when the laryngoscopic view was clear (Table 2). The LAR was always present in the visible 40 trials (100% of total visible 40 trials). However, judgment of the absence/presence of the LAR was not possible in six trials (13.0% of the 46 trials) due to a limited view of the larynx after the touch was applied. This failure in capturing the LAR occurred in one female (Subject 2) and two male subjects (Subject 6 and Subject 8; Table 1).

3) Swallowing reflex

The swallowing reflex occurred in16 trials (34.8% of the 46 trials; Table2). Among male subjects, there was only one instance in which a touch trial elicited a swallow. Conversely, four females swallowed in response to 15 touches in total. The pressure values of the touches that evoked the swallowing reflex ranged from 17.9mmHg to 350.0mmHg (Table1).

4) Cough reflex

The cough reflex occurred in five trials in one female subject only (Subject 5). The pressure measurements that evoked the cough reflex in the subject ranged from 17.9mmHg to 311.5mmHg (Table1).

5) Gag reflex

The gag reflex also occurred in three trials in one female subject (Subject 5) who presented the cough reflex in response to touch. The pressure measurements that evoked the gag reflex in the subject ranged from 60.6mmHg to 311.5mmHg (Table1).

Discussion

The study investigated the variability in the pressure delivered by examiners using the touch method. The study also reported the types of various subject responses to the touches. Additionally, raters' agreement in judging the absence/presence of the LAR in response to a touch was tested. The results showed that intensity of touches was inconsistent across all trials. The pressure levels exerted by the touches ranged from 17.9mmHg to the ceiling of 350.0mmHg. This range is important to highlight because a range of this magnitude may result in diagnostic inaccuracy. Aviv's work previously reported that if a patient does not elicit a LAR with an air pulse pressure of 6mmHg, then the patient has a severe sensory impairment (Aviv, Sacco, Mohr et al., 1997; Aviv, Sacco, Thomson et al., 1997). The current study found the mean pressure level exerted by directly touching the mucosa covering the arytenoid was 110.9±90.7mmHg - much higher than the stimulus level used for air pulse stimulation (Aviv, Sacco, Thomson et al., 1997). In the touch method, the direct contact pressure between the

probe of the pressure sensor and the laryngeal mucosa is recorded whereas in the air pulse method, the reported values are the air pressures produced by the air pulse stimulator. Clearly, the values obtained by these two different techniques are not comparable due to the fundamental differences in pressure acquisition. If we could generalize Aviv's definition of severe sensory deficits, then a person who exhibited the LAR in the current study may still have a 'sensory deficit'. However, it also suggests that if a person does not display the LAR, then they may have a sensory deficit. Thus, it is possible that the direct contact method is useful clinically when investigators aim to identify patients who have very severe laryngeal sensory deficits.

The study also revealed that there was a difference between the means of the pressure levels of touch exerted by the two examiners. This means that the variability in pressure measurements was related to difference in examiners' technique and not from different characteristics of the subjects tested. One possible explanation for this difference is examiners' years of experience with the touch method; Examiner 1 had two years of experience versus Examiner 2 had more than 20 years of experience. Years of experience is a variable that would be worthy of further investigation to determine its influence on pressure exerted.

With regard to types and consistency of subject response, the LAR and subject report consistently occurred in response to the touch in healthy adults in this sample. On the other hand, cough, gag, and swallowing reflexes did not occur consistently. Moreover, these other types of

responses were less consistently elicited by the scope touch stimulus. For example, one subject presented a cough in response to a touch, but the subject did not cough in response to another touch that exerted much higher pressure than the one that previously evoked a cough. This finding suggests that the absence of the LAR or subject response may be the most reliable marker of sensory dysfunction, while cough, gag, and swallowing reflexes may be questionable as markers of sensory dysfunction. The subjects consistently felt the touch stimulus. However, the way they perceived the touch seemed to be different. For example, one subject reported the touch felt scratchy, but another subject perceived the touch as a very subtle sensation. This variability among the healthy subjects in perceiving the touch stimulus may have contributed to some of the inconsistency in subject report.

One drawback of using the LAR as a marker for sensory function in the touch method is that the absence/presence of an LAR was not able to be rated by the examining clinicians in 6 out of 46 (13%) of the total attempts due to poor visualization. This generally occurred because a clear endoscopic view of a quick, brief movement of the vocal folds was sometimes difficult to obtain when the laryngoscope was very close to the arytenoid or touching the surface. Recall that in this study, the LAR was judged after the examination by two independent raters viewing the recorded exam, playing the video frame by frame. Thus, when viewing and rating the results

in a live examination, examiners may not be able to evaluate the LAR consistently when the view of the larynx may be obscured.

There were several limitations to this investigation. First, our study included only two examiners. There is likely to be more variability in pressures when multiple examiners with varying years of experience performing the touch method. Second, three pressure values exceeded the maximum measurable values of the fiberoptic sensor. Due to this ceiling effect in the instrumentation, the true maximum values that were exerted by the two examiners could not be determined, as they were greater than 350.0mmHg. Third, differences in the exact location where the touches were applied on the laryngeal mucosa may be another potential variable. Although the examiners were instructed to apply a touch to the mucosa covering the left arytenoid as described in Figure 2, it was not possible for the examiners to control the tip of the laryngoscope to consistently touch the exact same location in the targeted region. Further, each individual has a slightly different shape of the arytenoid, which made it even more difficult for the examiners to consistently touch the exact same location on the mucosa covering the arytenoid in the different subjects. This variability in the region where the touch was applied may have produced a variability in pressure measurements exerted by the tip of the scope. For example, touches applied to the lateral surface of the arytenoid might produce different pressure from the touches applied to the mucosa on top surface of the arytenoid. Further investigation is

needed to examine whether or not this variability could be diminished by training endoscopists to constantly deliver touches to the exact same location. Fourth, duration of the touch applied to the mucosa might also have varied across the trials, possibly affecting the presence/absence of the LAR. The aims of this study did not include duration measures, but analyzing the duration of touch is an important variable that is worthy of inclusion in future studies. Fifth, the pressure measures for each peak, synced with the laryngoscopic view, were not submitted to reliability testing. Finally, it may be argued that the use of lidocaine spray might have altered the results by depressing sensation and further investigation on the influence of anesthesia on airway sensation and the touch test in particular is warranted (Kamarunas, McCullough, Mennemeier, & Munn, 2015; O'Dea et al., 2015).

Conclusion

The study investigated the variability in the pressure delivered by clinicians using the touch method. It demonstrated a wide range of pressures and inconsistent pressure levels between examiners. These limitations of the touch method may lead to imprecise diagnostic information when testing individuals with mild-moderate sensory deficits. The most consistent responses to the touch test included subject response and the LAR. Given the frequent use of the touch method in clinical endoscopic swallowing evaluation, and its potential value in assessing

laryngeal sensory function, further research is needed to establish the validity and precision of this diagnostic method.

Acknowledgments

This study was supported by the Dudley Allen Sargent Research Fund.

The authors thank Edel McNally, MS, CCC-SLP, Rebecca Scheel, MS, CCC-SLP, BRS-S and Michael J. Walsh, M. Ed, CCC-SLP for their clinical advice and grading of the samples. We also thank Katey Felling, MS, for editorial assistance and Joe Lavoie of Pentax Medical for his support in technical issues.

Figure Legends:

Figure 1. Equipment interface

Figure 2. Laryngoscopic view of a touch and the corresponding pressure reading recorded on the Digital Swallowing Work Station

A: Laryngoscopic view from the monitoring scope showing the moment when the sensory scope came into contact with the mucosa covering the arytenoid.

B: Laryngoscopic view from the sensory scope used for testing. The entire view is obstructed by the laryngeal mucosa.

C: A schematic image of pressure waveform. Pressure waveform with arrow at maximum pressure reached while the scope is in contact with the mucosa.

References

Aviv, J. E., Kim, T., Sacco, R. L., Kaplan, S., Goodhart, K., Diamond, B., & Close, L. G. (1998). FEESST: A new bedside endoscopic test of the motor and sensory components of swallowing. *The Annals of Otology, Rhinology, and Laryngology, 107*(5 Pt 1), 378-387.

Aviv, J. E., Sacco, R. L., Mohr, J. P., Thompson, J. L., Levin, B., Sunshine, S., . . . Close, L. G. (1997). Laryngopharyngeal sensory testing with modified barium swallow as predictors of aspiration pneumonia after stroke. *The Laryngoscope, 107*(9), 1254-1260.

Aviv, J. E., Sacco, R. L., Thomson, J., Tandon, R., Diamond, B., Martin, J. H., & Close, L. G. (1997). Silent laryngopharyngeal sensory deficits after stroke. *The Annals of Otology, Rhinology, and Laryngology, 106*(2), 87-93.

Aviv, J. E., Spitzer, J., Cohen, M., Ma, G., Belafsky, P., & Close, L. G. (2002). Laryngeal adductor reflex and pharyngeal squeeze as predictors of laryngeal penetration and aspiration. *The Laryngoscope, 112*(2), 338-341.

Bradley, R. M. (2000). Sensory receptors of the larynx. *The American Journal of Medicine, 108 Suppl 4a*, 47S-50S.

Domer, A. S., Kuhn, M. A., & Belafsky, P. C. (2013). Neurophysiology and clinical implications of the laryngeal adductor reflex. *Current Otorhinolaryngology Reports, 1*(3), 178-182.

Kamarunas, E., McCullough, G. H., Mennemeier, M., & Munn, T. (2015). Oral perception of liquid volume changes with age. *Journal of Oral Rehabilitation, 42*(9), 657-662.

Kaneoka, A., Krisciunas, G. P., Walsh, K., Raade, A. S., & Langmore, S. E. (2014). A comparison of 2 methods of endoscopic laryngeal sensory testing: A preliminary study. *The Annals of Otology, Rhinology, and Laryngology, 124*(3), 187-193.

Kaneoka, A., Krisciunas, G. P., Walsh, K., Raade, A. S., & Langmore, S. E. (2015). A comparison of 2 methods of endoscopic laryngeal sensory testing: A preliminary study. *The Annals of Otology, Rhinology, and Laryngology, 124*(3), 187-193.

Langmore, S., Kenneth, S., & Olsen, N. (1988). *Fiberoptic endoscopic examination of swallowing safety: A new procedure. Dysphagia,* 1988;2(4):216-9.

Leow, L. P., Beckert, L., Anderson, T., & Huckabee, M. L. (2012). Changes in chemosensitivity and mechanosensitivity in aging and parkinson's disease. *Dysphagia, 27*(1), 106-114.

McHugh, M. L. (2012). Interrater reliability: The kappa statistic. *Biochemia Medica, 22*(3), 276-282.

O'Dea, M. B., Langmore, S. E., Krisciunas, G. P., Walsh, M., Zanchetti, L. L., Scheel, R., . . . Butler, S. G. (2015). Effect of lidocaine on swallowing during FEES in patients with dysphagia. *The Annals of Otology, Rhinology, and Laryngology,* 124(7), 537-44.

Onofri, S. M., Cola, P. C., Berti, L. C., da Silva, R. G., & Dantas, R. O. (2014). Correlation between laryngeal sensitivity and penetration/aspiration after stroke. *Dysphagia, 29*(2), 256-261.

Phua, S. Y., McGarvey, L. P., Ngu, M. C., & Ing, A. J. (2005). Patients with gastro-oesophageal reflux disease and cough have impaired laryngopharyngeal mechanosensitivity. *Thorax, 60*(6), 488-491.

Sato, S., Fujishima, I., Setsu, K., Katagiri, N., Inao, R., & Mizuma, M. (2002). Evaluation for dysphagia by testing laryngeal sensation with a flexible laryngoscope . *The Japanese Journal of Dysphagia Rehabilitation, 6*(4), 44-52.

Shock, L. A., Gallemore, B. C., Hinkel, C. J., Szewczyk, M. M., Hopewell, B. L., Allen, M. J., Lever, T. E. (2015). Improving the utility of laryngeal adductor reflex testing: A

translational tale of mice and men. *Otolaryngology-Head and Neck Surgery, 153*(1), 94-101.

Sulica, L., Hembree, A., & Blitzer, A. (2002). Swallowing and sensation: Evaluation of deglutition in the anesthetized larynx. *The Annals of Otology, Rhinology, and Laryngology, 111*(4), 291-294.

Table 1 Pressure measurements and subjects' responses

Subject	Sex	Age	Trial	Examiner	Pressure (mmHg)	Subject report	LAR	Swallow	Cough	Gag
1	female	39	1	1	77.0	present	present	present	absent	absent
1			2	1	24.9	present	present	absent	absent	absent
1			3	1	63.0	present	present	absent	absent	absent
1			4	2	21.4	present	present	present	absent	absent
1			5	2	350.0	present	present	present	absent	absent
1			6	2	.	present	present	present	absent	absent
2	female	42	1	1	85.4	present	present	absent	absent	absent
2			2	1	.	present	present	present	absent	absent
2			3	1	42.0	present	present	present	absent	absent
2			4	2	108.5	present	present	absent	absent	absent
2			5	2	32.9	present	cannot judge	absent	absent	absent
2			6	2	136.2	present	present	absent	absent	absent
3	male	41	1	2	232.4	present	present	absent	absent	absent
3			2	2	246.8	present	present	absent	absent	absent
3			3	1	273.7	absent	present	absent	absent	absent
3			4	1	309.8	present	present	absent	absent	absent
3			5	1	49.0	present	present	absent	absent	absent

3			6	2	298.2	present	present	absent	absent	absent
4	male	35	1	1	143.5	present	present	absent	absent	absent
4			2	1	93.8	present	present	absent	absent	absent
4			3	1	127.4	present	present	absent	absent	absent
4			4	2	132.0	present	present	absent	absent	absent
4			5	2	350.0	present	present	absent	absent	absent
4			6	2	283.5	present	present	absent	absent	absent
5	female	25	1	1	60.6	present	present	absent	absent	present
5			2	1	79.1	present	present	present	present	present
5			3	1	17.9	present	present	present	present	absent
5			4	2	311.5	present	present	present	present	absent
5			5	2	263.6	present	present	present	present	present
5			6	2	157.2	present	present	absent	present	absent
6	male	62	1	1	132.7	present	cannot judge	absent	absent	absent
6			2	1	56.4	present	present	present	absent	absent
6			3	1	131.3	present	cannot judge	absent	absent	absent
6			4	2	97.3	present	cannot judge	absent	absent	absent
6			5	2	25.2	present	present	absent	absent	absent
6			6	2	105.4	present	present	absent	absent	absent
7	female	37	1	2	134.1	present	present	present	absent	absent

7			2	2	34.0	present	present	present	absent	absent
7			3	2	37.8	present	present	present	absent	absent
7			4	1	71.1	present	present	present	absent	absent
7			5	1	43.8	present	present	absent	absent	absent
7			6	1	17.9	present	present	present	absent	absent
8	male	33	1	2	104.0	present	present	absent	absent	absent
8			2	2	21.0	present	present	absent	absent	absent
8			3	2	21.4	present	cannot judge	absent	absent	absent
8			4	1	44.1	absent	cannot judge	absent	absent	absent
8			5	1	350.0	present	present	absent	absent	absent
8			6	1	22.4	absent	present	absent	absent	absent

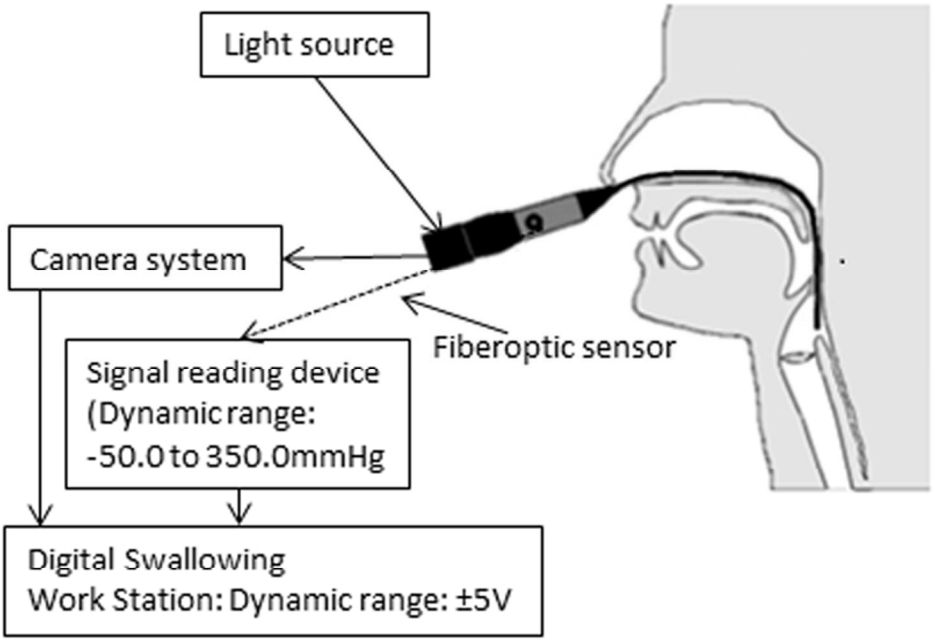
Table 2 Types of respons

	Number of responses (%)		
Type of response	Present	Absent	Could not be determined
Subject report	43 (93.5)	3 (6.5)	0
LAR	40 (87.0)	0 (0.0)	6 (13.0)
Swallow	16 (34.8)	30 (65.2)	0
Cough	5 (10.9)	41 (89.1)	0
Gag	3 (6.5)	43 (93.5)	0

Table 3 Three rater's judgment for the absence/presence of the LAR

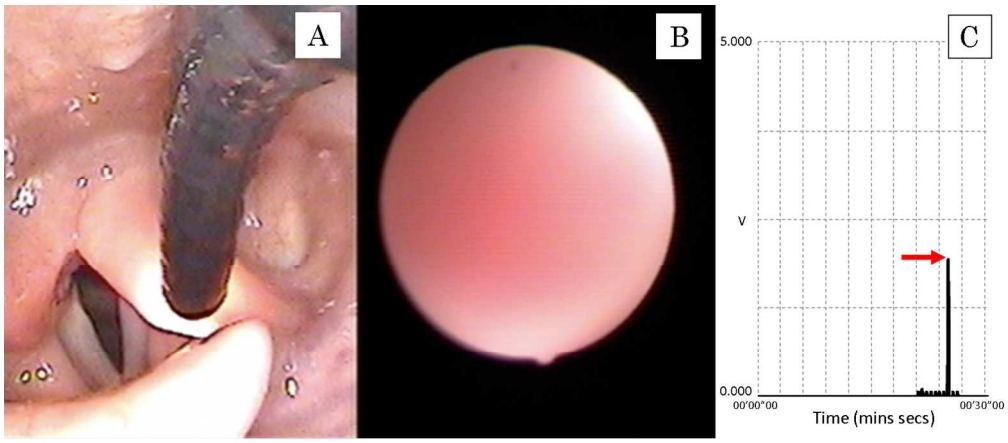
Trial No.	Subject	Rater 1	Rater 2	Rater 3	Final judgment
1	1	present	present		present
2	1	present	present		present
3	1	present	present		present
4	1	present	present		present
5	1	present	present		present
6	1	present	present		present
1	2	present	present		present
2	2	present	present		present
3	2	present	present		present
4	2	present	present		present
5	2	cannot judge	present	cannot judge	cannot judge
6	2	present	present		present
1	3	present	present		present
2	3	present	present		present
3	3	cannot judge	present	present	present
4	3	present	present		present
5	3	present	present		present
6	3	present	present		present
1	4	present	present		present
2	4	present	present		present
3	4	present	present		present
4	4	present	present		present
5	4	present	present		present
6	4	present	present		present
1	5	present	present		present
2	5	present	present		present
3	5	present	present		present
4	5	present	present		present
5	5	present	present		present

6	5	present	present		present
1	6	cannot judge	cannot judge		cannot judge
2	6	present	present		present
3	6	cannot judge	absent	cannot judge	cannot judge
4	6	cannot judge	absent	cannot judge	cannot judge
5	6	present	present		present
6	6	present	present		present
1	7	present	present		present
2	7	present	present		present
3	7	present	present		present
4	7	present	present		present
5	7	cannot judge	present	present	present
6	7	present	present		present
1	8	present	present		present
2	8	present	present		present
3	8	cannot judge	cannot judge		cannot judge
4	8	cannot judge	absent	cannot judge	cannot judge
5	8	present	cannot judge	present	present
6	8	present	present		present



1

111x77mm (200 x 200 DPI)



2

151x65mm (300 x 300 DPI)