Effects of Age, Gender, Bolus Volume and Viscosity on Acoustic Signals of Normal Swallowing

Yaş, Cinsiyet, Bolus Miktarı ve Bolus Yoğunluğunun Normal Yutmanın Akustik Sinyalleri Üzerine Etkisi

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Summary

Objective: The purpose of this investigation was to determine the effects of age, gender, bolus volume and bolus viscosity on the acoustic signals of normal swallows.

Materials and Methods: Healthy volunteers (n=146) ranging from 3 to 85 years of age participated in the investigation. Subjects were grouped by age: 3-5, 18-25 and 70-85 years of age. Subjects performed a series of swallows that were randomized according to volume and viscosity. A total of 3056 swallows were analyzed. Four temporal events were compared; acoustic onset, acoustic peak, acoustic spike associated with the small non-inspiratory flow, and acoustic offset.

Results: In the youngest group, a significant effect was found for volume, viscosity and gender for the time of acoustic onset ($p<0.01$). In the oldest age group, the variability for acoustic onset was much higher than in the other age groups ($p<0.01$). The oldest group had a substantially longer acoustic duration, especially for men ($p<0.01$). Additionally, a significant effect for viscosity and volume for the time of acoustic offset was found in the oldest age group ($p<0.01$).

Conclusion: During normal swallowing, it was determined the effects of age, gender, bolus volume, and bolus viscosity on the acoustic signals of normal swallow. *Turk J Phys Med Rehab 2007;53:94-9.*

Key Words: Swallowing, acoustic signal, age, gender, bolus volume, bolus viscosity

Özet

Amaç: Bu araştırmada normal yutma sırasında, yaş, cinsiyet, bolus miktarı ve bolus yoğunluğunun akustik sinyaller üzerine etkisinin ortaya konulması amaçlanmıştır.

Gereç ve Yöntem: Yaşları 3-85 arasında (n: 146) sağlıklı gönüllüler çalışmaya alındı. Katılımcılar yaşa göre; 3-5 yaş, 18-25 yaş, 70-85 yaş olacak şekilde gruplandı. Randomize olarak bolus miktarı ve yoğunluğuna göre, katılımcılar yutma serileri gerçekleştirdiler. Toplam 3056 yutma analiz edildi. Dört eylem karşılaştırıldı: akustik başlangıç, akustik pik, küçük inspiratuvar olmayan akımla ilişkili çıkış, akustik bitiş.

Bulgular: Akustik başlama zamanı için, miktar, yoğunluk ve cinsiyet açısından en genç grupta anlamlı farklılık bulundu ($p<0,05$). En yaşlı grupta, akustik başlama zamanındaki değişkenlik diğer yaş gruplarından daha yüksekti ($p<0,05$). Akustik süre, erkeklerde belirgin olmak üzere, en yaşlı grupta en uzundu ($p<0,05$). Ayrıca, en yaşlı grup için, akustik bitiş zamanında miktar ve yoğunluk açısından anlamlı etki saptandı ($p<0,05$).

Sonuç: Normal yutma sırasında, yaş, cinsiyet, bolus miktarı ve bolus yoğunluğunun akustik sinyaller üzerine etkisi ortaya konulmuştur. *Türk Fiz Tıp Rehab Derg 2007;53:94-9.*

Anahtar Kelimeler: Yutma, akustik sinyal, yaş, cinsiyet, bolus miktari, bolus yoğunluğu

Introduction

Pharyngeal swallows are associated with a sequence of sounds audible with instruments such as the stethoscope, accelerometer or microphone held behind the larynx (1). Hamlet et al. (2) stated that movements such as elevation of the hyoid and larynx as well as movement of the epiglottis may comprise part of the acoustic signal. Additionally, those investigators indicated that the acoustic signal corresponded to movement of the bolus through the upper esophageal sphincter.

Researchers have used acoustic techniques to examine various parameters of the normal swallow (1-8). It has been

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reported that the normal swallowing sound has an average duration of 250 to 800 milliseconds, an intensity between 4-41 dB and a frequency range of 0 to 8 kHz, with a predominance of acoustic energy between 0 and 3 kHz (8). Given that the spectral characteristics of an acoustic signal are influenced by the characteristics of the microphone that is used and by signal conditioning, frequency characteristics can be difficult to compare across investigations. Furthermore, signal intensity via a neck microphone is altered as a function of the filtering characteristics of the neck muscles, adipose tissue etc.

Physiologically the normal swallow shows differences with age, gender, bolus volume and viscosity (9-15). Few investigators (3,7,8,16) hypothesize that if the normal swallow were affected by these variables, the acoustic signals of the swallow might also be affected. Consequently they have studied the effects of age, gender, bolus volume and bolus viscosity on the timing of the acoustic signature of the swallow. But investigators have reported different results for these variables (7,8,17). It is, of course possible that methodological variations can explain some of the differences in the studies. The quality of recordings depended upon factors such as the placement of the microphone near the cricoid cartilage and its orientation in the direction of the esophagus (6).

The acoustic sounds produced during swallowing and the sources of such sounds, are not entirely understood. Researchers and clinicians have proposed that the acoustic signals produced during swallowing may be one physiologic parameter that can be utilized to determine if an individual has adequate airway protection during swallowing (6,8,18)

It has been suggested that correlating swallowing sounds with known physiological events that occur during swallowing would give cervical auscultation more power as a diagnostic tool (19). Zenner et al. (20) reported that cervical auscultation was a sensitive and specific method for determining the presence of aspiration while Stroud et al. (21) reported that it was not. There does not appear to be a clear, well-accepted theory as to the physiological cause of portions of the swallowing sounds, thus limiting the diagnostic value of cervical auscultation (19). Furthermore, some clinicians have discussed the value of assessing the duration of the acoustic signal as an indication of successful bolus passage. However there is limited published information (2,4,8,16) on the duration of the acoustic signal during a normal swallow.

To date, no research has been reported to investigate the effects of age, gender, bolus volume and bolus viscosity on the acoustic signals of the normal swallow within one study. Similarities and differences in the biomechanics of swallowing among different age groups and across gender may be important to consider during clinical evaluations. Effects of bolus volume and viscosity are often important considerations in the treatment of patients with dysphagia. Therefore, the purpose of this study was to establish the normative data for temporal aspects the acoustic signal as a function of age, gender, bolus volume and bolus viscosity during the swallow.

Materials and Methods

Subjects

Healthy volunteers (n=146) ranging from 3 to 85 years of age participated in the investigation. The subjects were grouped by age in the following manner: Group 1: 3-5 years of age (n=20 male, 23 female). Group 2: 18-25 years of age (n= 20 male, 20 female). Group 3: 70-85 years of age (n=30 male, 33 female). All of the subjects were in good health and none of the subjects had any history of dysphagia, voice problems, pulmonary disease, stroke, neurological disease, or head/neck cancer, and no speech or language difficulty. No subjects were taking any medications that might affect any of the three stages of deglutition. All subjects were advised of the risks of this investigation, and signed the Human Subjects Consent Forms that had been approved by the University of Illinois at Urbana-Champaign and by Carle Hospital and Foundation.

Instrumentation

Data were collected in the traditional manner using a respirodeglutometer (RDG) (Glottal Enterprises, Syracuse, NY, USA). The RDG is a four-channel instrument and a schematic diagram of the instrumentation is shown in Figure 1. The first channel, which displays a trigger signal, serves as the indicator of the delivery of a food or liquid bolus into the oral cavity. The experimenter uses a hand held switch to produce a 5-V signal. The shape and duration of the signal varies according to the bolus volume and viscosity that is presented to the subject.

The second input is from a nasal canula, 120 cm in length. This length was selected in order to permit the subject to sit comfortably and be free to move his/her head as needed. The proximal end of the cannula is placed at the entrance to the nares and the distal end is connected to a pressure transducer within the RDG. This micromanometer provides information regarding the direction of flow as an integration of positive or negative air pressure over time. A negative pressure, indicative of inspiration, is recorded as negative voltage, and positive pressure, indicative of expiration, as positive voltage. Voltage is zero during the period of apnea. Because the nares are not completely occluded, air volume cannot be determined with the RDG.

The third input is an acoustic signal received from a surface microphone that has been placed on the side of the neck immediately posterior to the thyroid cartilage and inferior to the angle of the mandible. The microphone was held and secured in place around the neck with a Velcro and elastic band. The microphone has a four pole, high-pass Butterworth filter with a high frequency cutoff at 100 Hz.

The final RDG input is from submental surface electromyography (SEMG). SEMG is used to monitor the activity of muscles of the submental region during the swallow.

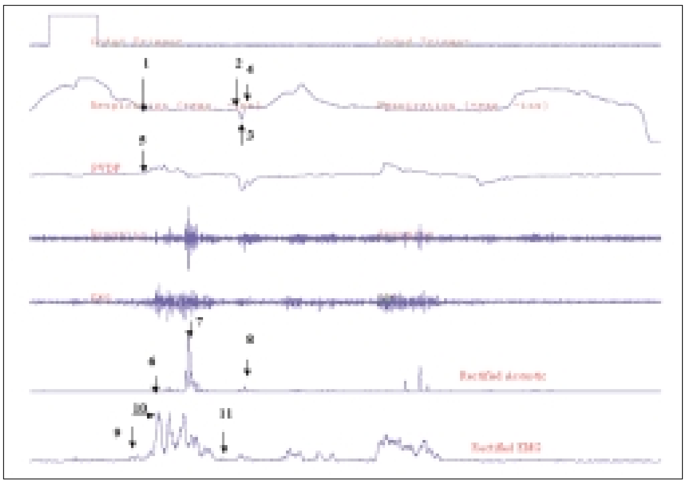

Figure 1. The respirodeglutometer (RDG): a schematic diagram of the instrumentation.

Bipolar surface electrodes were evenly placed on both sides of the midsagittal line of the submental region and the ground was attached to the forehead or to the mastoid process. These electrodes were connected to a differential amplifier within the instrument box and are low-pass filtered at 5 kHz. Although the SEMG signal was recorded and can be seen in Figure 1, it was not part of the present investigation.

Input from the four analog waveforms were digitized and recorded onto a Dell desktop computer using CODAS (DATAQ, Akron). The CODAS signals for each swallow were digitized at 1000 samples/sec/channel and input to the computer at 10V peak-to-peak for channels 2 through 4 and as a 5V positive signal for the trigger. Both the acoustic and SEMG signals were later rectified. The rectified acoustic signal was smoothed with a moving average filter of 10-samples/point and the SEMG was smoothed with a moving average filter of 25 samples/point.

However, only the acoustic signal was analyzed.

Procedure

The subjects performed a series of swallows that were randomized according to volume and viscosity. Patients fed themselves 5 and 10-ml measured volumes of liquid and pudding. Pudding was self-presented by spoon, and liquid with a ''nosey cup'' which is a cup that permits presentation without elevating the chin.

Data Analysis

Signals were smoothed and rectified using WINDAQ (DATAQ instruments). They were then input to MatLab for automated analysis. The user specified the area preceding and following the swallow, after which the program found the critical points for that specific swallow. The user then had the option of checking the points, confirming those points or performing an overwrite.

Because the onset of deglutition apnea showed considerable variability as a function of the oral preparatory phase of deglutition, all values were normalized to the offset of deglutition apnea (A_{off}) (Figure 1). The following temporal events were examined:

1. Acoustic onset: the point where the acoustic signal moved upward and continued to increase
2. Acoustic peak: the point in time of maximum acoustic energy during deglutition apnea (if two or more peaks showed the same amplitude, the first of the peaks was selected)
3. SNIF associated acoustic spike: The point in time of the maximum acoustic energy occurring closest to, and within −0.055 to +0.025 sec of the SNIF nadir.
4. Acoustic offset: The point in time after apnea onset at which the acoustic signal returned to baseline and stayed below baseline for no less than 0.05 sec. Acoustic offset minus Acoustic onset equals the duration of the acoustic signal.

Three temporal events were compared: Signal duration (acoustic offset-acoustic onset), acoustic peak, SNIF associated acoustic spike. These points are marked on Figure 1.

Statistical Procedures

The statistical analysis were done in Department of Statistics at University of Illinois. The results were analyzed using the Statistical Analyze System (SAS). Linear mixed models were used in this study. Observations below the 1 st percentile and above the 90th percentile. This typically removed more than 2% of the data because of missing values. A significance level of p£0.01 was determined a priori for each analysis technique. From the remaining observations all the ones that fall more than 10 MADs away from the median were removed. MAD stands for Median Absolute Deviation and is a robust measure of spread of the data.

A log transformation was used for the three age groups, and for the comparison between age groups. This means that if a difference was significant on the log scale, the corresponding ratio was significant on the original scale.

Results

Age 18-25 (Group 2) was chosen as the reference group to which other age groups were compared.

Acoustic Onset (Relative to Apnea Offset) (Table 1a-b)

For the 3-5 age group, only viscosity was significant at the 0.01 level. For pudding swallows the Acoustic Onset occurs on average 1.390 seconds before the Apnea Offset. For liquid swallows the Acoustic Onset occurs on average 1.989 seconds before the Apnea Offset. The difference between pudding and liquid is -0.599 seconds.

For the 18-25 age group, only viscosity was significant at the 0.01 level. For pudding swallows the Acoustic Onset occurs on average 1.938 seconds before the Apnea Offset. For liquid swallows the Acoustic Onset occurs on average 1.881 seconds before the Apnea Offset. The difference between pudding and liquid is 0.057 seconds.

Therefore, we look at the difference between the two age groups in mean log time from Acoustic Onset to Apnea Offset for liquid and pudding swallows.

The difference between the two age groups in mean log time from Acoustic Onset to Apnea Offset was significant for both liquid and pudding swallows at the 0.01 level.

For the 70-85 age group, volume was significant as well as the interaction between gender and viscosity at the 0.01 level. But volume was not significant for age group 18-25. In addition to that, in a model with age, volume, viscosity and gender, the interaction between volume and age is not significant.

Therefore we look at the differences between the two age groups across all levels of gender and viscosity only.

The difference between the two age groups in mean log time between Acoustic Onset and Apnea Offset was significant for all combinations of the above variables at the 0.01 level.

Acoustic Apnea Peak (Relative to Apnea Offset) (Table 2a-b)

For 3-5 age group, viscosity, volume and their interaction are significant at 0.01 level. For water swallow, 5 ml and 10 ml have significant difference at 0.01 level. 10 ml results in longer mean acoustic apnea peak (0.846-0.585=0.261 second). For pudding swallows, this difference is not significant.

For 18-25 age group, only volume was significant at .01 level. Since the difference is small (0.036 second), we can combine volume 5 and 10 for this age group.

Therefore, we look at the difference between the two age groups in mean log acoustic apnea peak for liquid swallows with volume 5, with volume 10, and pudding swallows.

The difference between the two age groups in mean log Acoustic Apnea Peak was not significant for liquid swallows at 5ml, but significant at the 0.05 level for 10 ml. 3-5 age group has longer mean acoustic apnea peak (0.846-0.437=0.409 second). There difference between the age groups for pudding swallows was significant at 0.01 level. 3-5 age group has longer mean acoustic apnea peak (0.421-0.402=0.019 second).

For 70-85 age group, only viscosity is significant at 0.01 level.

Therefore, we look at the difference between the two age groups in mean log acoustic apnea peak for liquid and pudding swallows.

The difference between the two age groups in mean log Acoustic Apnea Peak was significant for both liquid and pudding swallows at the 0.01 level. For water swallows, 70-85 age group has longer mean acoustic apnea peak (0.554-0.423=0.131 second). For pudding swallows, 70-85 age group has longer mean acoustic apnea peak (0.516-0.402=0.114 second).

SNIF associated acoustic spike (Relative to Apnea Offset) (Table 3)

For 3-5 age group, only viscosity was significant at 0.01 level. Pudding swallows had longer Acoustic Sniff Peak by 0.012 (0.083-0.071=0.012) second.

For 18-25 age group, only viscosity was significant at 0.01 level. Pudding swallows had longer Acoustic Sniff Peak by 0.006 (0.081-0.075=0.006) second.

Therefore, we look at the difference between the two age groups in mean log acoustic sniff peak for liquid and pudding swallows.

The difference between the two age groups in mean log Acoustic Sniff Peak was not significant for both liquid and pudding swallows at the 0.05 level.

For 18-25 age group, only viscosity was significant at 0.01 level. Pudding swallows had longer Acoustic Sniff Peak by 0.006 (0.081-0.075=0.006) second.

For 70-85 age group, only viscosity is significant at .01 level. Pudding swallows had longer Acoustic Sniff Peak by 0.016 (0.099-0.083=0.016) second.

Table 1a. Mean values in Acoustic Onset (in seconds).

	Group 1 Mean±SD	Group 2 Mean±SD	Group 3 Mean±SD
Liquid	1.319±0.895	0.946±0.489	2.324±0.456
Pudding	0.998±0.734	0.838±0.446	2.389±0.466

Table 1b. Mean Difference in Acoustic Onset (in seconds).

	Groups 1 versus 2 (n for Group 1; n for Group 2)	Groups 3 versus 2 (n for Group 3; n for Group 2)
Liquid	0.373 (n=377; 513)	1.378* (n=843;513)
Pudding	0.160 (n=365,486)	1.551* (n=859;486)
Female Liquid	0.489 (n=216;256)	1.250* (n=455;216)
Female Pudding	0.127 (n=203;231)	1.282* (n=459;231)
Male Liquid	0.246 (n=161;257)	1.543* (n=388;257)
Male Pudding	0.226 (n=162;255)	1.876* (n=400;255)

*p<0.01

Therefore, we look at the difference between the two age groups in mean log acoustic apnea peak for liquid and pudding swallows.

The difference between the two age groups in mean log Acoustic Sniff Peak was not significant for both liquid and pudding swallows at the 0.01 level, but for pudding swallow, it was significant at 0.05 level.

Acoustic Offset (Relative to Apnea Offset)(Table 4a-b)

For the 18-25 age group, only viscosity was significant at the 0.01 level. For pudding swallows the Acoustic Offset occurs on average 0.971 seconds after the Apnea Offset. For liquid swallows the Acoustic Offset occurs on average 1.203 seconds after the Apnea Offset. The difference between pudding and liquid is 0.232 seconds.

For the 3-5 age group, no variable was significant at the .01 level.

Therefore, we look at the difference between the two age groups in mean time from Acoustic Offset to Apnea Offset for liquid and pudding swallows.

The difference between the two age groups in mean time from Acoustic Onset to Apnea Offset was not significant for both liquid and pudding swallows at the 0.01 level.

For the 70-85 age group, volume and viscosity were significant at the 0.01 level. But volume was not significant for age group 18-25. For liquid swallows, Acoustic Offset occurs on average 0.789 seconds after Apnea Offset for volume=5 ml and 0.890 seconds after Apnea Offset for volume=10 ml. For pudding swallows, Acoustic Offset occurs on average 0.435 seconds after Apnea Offset for volume=5 ml and 0.551 seconds after Apnea Offset for volume=10 ml.

Therefore we look at differences between the two age groups across all levels of volume and viscosity.

Negative values mean that the event took place after Apnea Offset.

The difference between the two age groups in mean time between Acoustic Offset and Apnea Offset was significant at the 0.01 level for both volumes and both viscosities.

Mean differences in acoustic duration were seen in Figure 2.

Discussion

The present investigation studied the acoustic patterns during the pharyngeal stage of swallowing and compared those patterns in three healthy age groups, by gender, bolus volume

Table 2a. Mean values in Acoustic Peak (in seconds).

	Group 1 Mean±SD	Group 2 Mean±SD	Group 3 Mean±SD
Liquid	0.614±0.450	0.423±0.156	0.553±0.247
Pudding	0.421±0.402	0.402±0.172	0.516±0.265

Table 2b. Mean Difference in Acoustic Peak (in seconds).

	Groups 1 versus 2	Groups 3 versus 2
Liquid 5 ml	0.176	0.134*
Liquid 10 ml	0.408	0.128*
Liquid	0.291	0.130*
Pudding	0.019*	0.114*

*p<0.01

and bolus viscosity. A previous study (9) recommended use of the self-feeding condition for the collection of normative data. The investigators in the present study agreed that a self-feeding condition more closely resembles that which is performed by able-bodied, healthy individuals and therefore all measures were made during the self-fed condition.

The current study showed a significant effect for volume for all three age groups. Additionally, a significant age by volume interaction for acoustic onset and acoustic offset was found for the oldest age group (group 3). A significant age by volume effect was found for the time of the acoustic apnea peak in youngest age group (group 1). The oldest group had significantly longer duration of the acoustic signal than that of the middle age group. The time of the acoustic peak for the youngest group (group 1) was significantly earlier than the middle age group. Some investigators established the effect of age for normal swallowing sound (8,17). Some studies (17,22,23) reported that the duration of swallowing sound increases with older age. On the other hand, Cichero et al. (8) reported no differences between the middle and older groups, and found a significant age-by-volume interaction (only 5-ml volume) in the youngest group. This value is shorter than middle and older groups. Boiron et al. (7) results showed that the duration of acoustic signals increased according to the volume swallowed. On the other hand, Cichero et al. (8) found that swallowing sound duration decreased as bolus volume increased. Our technique was similar to that of Cichero et al but included large age range of subjects and different bolus viscosity.

Previous researchers (8,16,17) documented the effect of gender on the acoustic sounds of normal swallowing. Lebel et al. (17) and Takahashi et al. (16) noted that women have ashorter duration of swallowing sounds than men. Some researchers (8, 22, 24) did not find any statistically significant results. Our study showed that men have longer acoustic onset time than women only in the oldest age group.

Table 3. Mean values in Acoustic Sniff Peak (in seconds).

	Group 1 Mean±SD	Group 2 Mean±SD	Group 3 Mean±SD
Liquid	0.071±0.066	0.075±0.046	0.083±0.054
Pudding	0.083±0.061	0.081±0.042	0.099±0.063

Table 4a. Mean values in Acoustic Offset (in seconds).

	Group 1 Mean±SD	Group 2 Mean±SD	Group 3 Mean±SD
Liquid	-0.130±0.535	-0.231±0.412	-0.842±0.685
Pudding	-0.128±0.490	-0.105±0.308	-0.493±0.356

Table 4b. Mean Difference in Acoustic Peak (in seconds).

	Groups 1 versus 2	Groups 3 versus 2
Liquid	0.083	-0.611*
Pudding	-0.031	-0.388*
5 ml	0.000	-0.459*
10 ml	0.047	-0.553*

*p<0.01

The current study showed a significant effect for viscosity in acoustic onset time for all three age groups. The oldest group had a significantly longer duration. One can hypothesize that the increased time between acoustic onset and apnea offset with advanced age may be related to; premature spillover into the pharynx preceding the swallow and a longer time employed before airway opening. With healthy young adults, our laboratory has found that SNIF onset occurred at the same time as the completion of velar depression (with the young adults, the SNIF associated acoustic spike occurred an average of 5 ms later) (Perlman et al JSLHR-in press). The oldest group had significantly longer duration between the SNIF associated acoustic spike and apnea offset. It is possible that the SNIF associated acoustic spike is related to air movement associated with velar depression. The elderly may have begun velar depression before, or at a slower rate, than younger subjects. No significant differences were observed across age groups for the duration between the SNIF associated acoustic spike and apnea offset.

The present study also found a significant effect for viscosity in acoustic apnea peak value in the youngest and the oldest age groups. In the youngest age group, acoustic apnea peak time was significantly longer than the middle age group for pudding swallow. And this value was significantly longer than that of the middle age group for pudding and water swallow in the oldest group. Boiron et al. (7) reported that yogurt showed a reduction in the duration of the swallowing signals for all volumes compared with water and explained that the duration of the opening of the upper esophageal sphincter (UES) was greater for liquids which spread across the pharynx, whereas substances with greater consistency pass more quickly through the UES and in more compact manner (13,17,25). Perlman et al. (26) did not find any statistically significant results between different viscosities. On the other hand, Youmans et al (22) reported that a significant correlation was found between durational variables and bolus consistencies.

Normative data was established for temporal aspects the acoustic signal as a function of age, gender, bolus volume, and bolus viscosity during normal swallow. The acoustic signals associated with the swallow and the duration of the acoustic signal as an indication of successful bolus passage. What does that mean for the clinical application of acoustic signals? Videofluoroscopic swallowing study (VFSS) is generally regarded

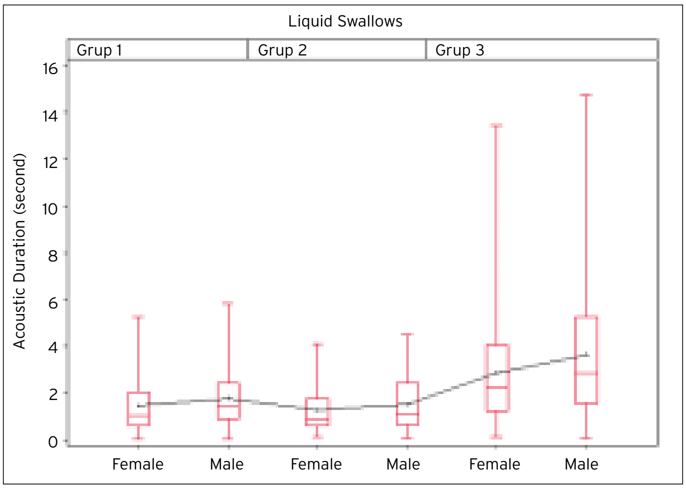

Figure 2. Mean difference in acoustic duration (in seconds).

as a standard method of dysphagia evaluation. There are a few limitations in using VFSS as a screening test. These limitations include the patients' exposure to radiation during the study and availability of equipment and personnel. A fiberoptic endoscopic swallowing study has the advantage that it is possible to perform it at the bedside and that it provides comparable information to VFSS in assessing the risk of aspiration. Fiberoptic endoscopic swallowing study may cause discomfort to patients during the procedure and may be difficult to use as a quick screening tool. A safe and time efficient screening test is needed to augment the clinical bedside evaluation for dysphagia. The detection of the acoustic signal is a safe, noninvasive, and reliable screening tool for patients with dysphagia which requires limited patient cooperation and can detect patients at high risk of clinically significant aspiration. As a result of this, determining the change in acoustic signals is useful to us to provide information on the physiology of swallowing in patients with swallowing problems. Especially during early stages of patients with silent aspiration risks whom we can only have a bedside examination, it is important to evaluate acoustic signals with portable instruments in order to protect the patient from complications and in order to provide the patient with an early rehabilitation program. However, as it still does not show the airway directly, according to our current data, it needs to be evaluated with bedside examination and VFSS.

Looking at results in patients with dysphagia caused by different illnesses, only two studies by the same research group (27,28) report on characteristics of acoustic signals in dysphagia patients. However, the number of clinical studies is not large enough to be able to comment on the change of these signals in dysphagia patients. These results could serve as a reference point for future studies into normal swallowing across multiple bolus consistencies and volumes and eventually be compared with disordered swallowing. In a future study researchers will evaluate the reliability and validity of acoustic signals connected with parameters of clinical swallow examination in different patient groups.

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